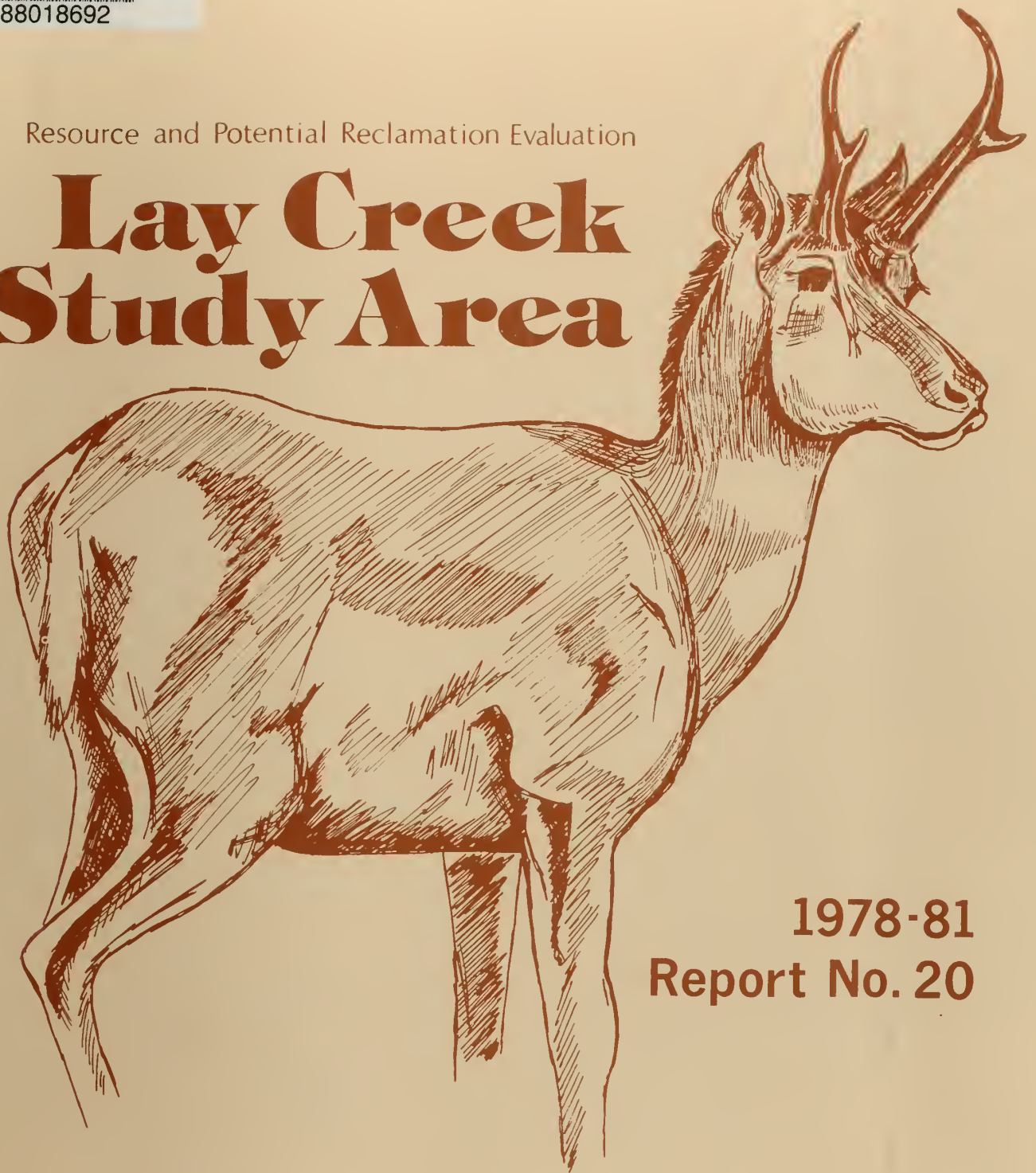




88018692

Resource and Potential Reclamation Evaluation

Lay Creek Study Area



1978-81
Report No. 20

United States Department of the Interior
Bureau of Land Management
Bureau of Reclamation
Geologic Survey

LAY CREEK STUDY SITE REPORT
Published September 1981

The Federal Coal Management Program has been designed as an interagency cooperative effort to meet National energy objectives.

Lay Creek Study Site Report was prepared through the efforts of the U.S. Department of the Interior, principally, the Bureau of Land Management, Geological Survey, and Bureau of Reclamation. The study effort began in 1978 and was concluded in 1981 with the publication of this report.

The area described in this report has been tentatively determined to be a potential Federal coal development area. The purpose of this report is to provide information on the area's reclamation potential should coal development occur. This report will assist managers in making final Federal coal leasing decisions.

Editor's Note: In order to more closely associate the EMRIA program with the Federal Coal Management Program, the name "EMRIA" was officially dropped from use in May 1981. The responsibilities of the EMRIA program now come under "Technical Investigations in Support of the Federal Coal Management Program."

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**1978-81
Report No. 20**

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CHAPTER I

INTRODUCTION

This resource and potential reclamation evaluation is prepared for the Lay Creek study site of northwestern Colorado. It is a presentation of the available data gathered by the various Federal agencies involved in the Federal Coal Management Program of the Department of the Interior. This program is the result of a need to not only conserve but also to develop our energy resources to satisfy the demand of our society and to ensure an acceptable nondegradation of the air, water, soils, vegetation, and wildlife of affected areas. This demand and the world energy crisis have focused the attention of the Nation on the bituminous and subbituminous coal resources existing in the Western States. This attention is due to the abundance, simplicity of extraction, and the high quality of coal in the Rocky Mountains and the Northern Great Plains Coal Provinces.

The Department of the Interior and principally the Bureau of Land Management has the responsibility to provide the overall management and guidance for acceptable reclamation of the lands subject to disturbance by resource development.

Purpose

The purpose of the study is to assure adequate baseline data for choosing optimum reclamation and rehabilitation objectives and for establishing appropriate data and interpretations for preparation of lease stipulations through site-specific preplanning of surface mining and reclamation.

Objectives

1. To analyze and quantify environmental impacts from surface mining of coal minerals in the Lay Creek, Colo., area.
2. To provide resource and impact information to the leasing site selection procedures as set forth by the Secretary of the Interior.
3. To provide environmental resource information needed to implement effective reclamation and rehabilitation programs and for the development of meaningful lease stipulations as required by the mined land reclamation program.
4. To provide resource and environmental impact information to support State and local regional development and land use planning efforts.



5. To determine the present and potential capability of the surface soil and subsurface resources to produce and maintain vegetation on known energy fuel deposits.
6. To provide physical and chemical data from which realistic stipulations may be prepared for energy mineral explorations, mining, and reclamation plans.
7. To provide data needed in the preparation of environmental impact statements, environmental analysis records, and to aid in the review of mining and reclamation plans for potential coal leasing activities in the vicinity of the study area.

Authority

Public Land Administration Act of July 14, 1969 (74 Stat. 506), Federal Land Policy and Management Act of 1976 (Public Law 94-579), and Surface Mining Control and Reclamation Act of 1977 (Public Law 95-87).

Responsibility

Bureau of Land Management

1. Select reclamation study site, with advice from the United States Geological Survey, for the investigation of vegetation, soil, geological structure, surface water, ground water, and coal resources.
2. Provide access to study site; prepare and provide for environmental clearances required to conduct the study.
3. Prepare, coordinate, issue, and monitor the execution of work orders.
4. Identify probable postmining land use and present land use.
5. Prepare inputs to the report covering wildlife, cultural and visual resources, and summary of regulations on mine-land reclamation.
6. Provide technical support, guidance, and flag dates to the other cooperating agencies.
7. Distribute technical data, reports, and reclamation and rehabilitation recommendations to the Bureau of Land Management field offices.



Bureau of Reclamation

1. Conduct land studies, including land classification for determining suitability of soil and bedrock material, soil inventory, and laboratory characterization program.
2. Conduct core drilling operations for procurement of core samples used for the characterization and analysis of the geologic overburden materials.
3. Map surface geology.
4. Prepare geologic logs on drill holes.
5. Collect and submit to Bureau of Land Management or Geological Survey coal samples.
6. Where required and as needed install casing in drill holes selected for ground water observation wells.
7. Characterize and interpret data available on soils and overburden materials as well as the substrata immediately below the coal resource in relation to reclamation potential and revegetation.
8. Advise and recommend suitable plant species for use in areas to be reclaimed.
9. Recommend reclamation techniques.
10. Coordinate, assemble, and print the final report.

U. S. Geological Survey

1. Assess reclamation potential based on water supply.
2. Prepare sediment yield data.
3. Prepare erodability data.
4. Determine rainfall-runoff relationships and analyze surface and subsurface waters for chemical quality.
5. Tabulate coal resource data, including resource estimates and analytical results.
6. Evaluate effects of mining on the area hydrology and downstream areas.

Location and Setting

The Lay Creek study site is located in northwestern Colorado, approximately 25 miles northwest of Craig, the county seat for Moffat County. The exact location is illustrated on Figure 1. The study area comprises approximately 3,645 acres and includes all or part of secs. 26, 27, 28, 29, 30, 31, and 32, T. 8 N., R. 93 W.

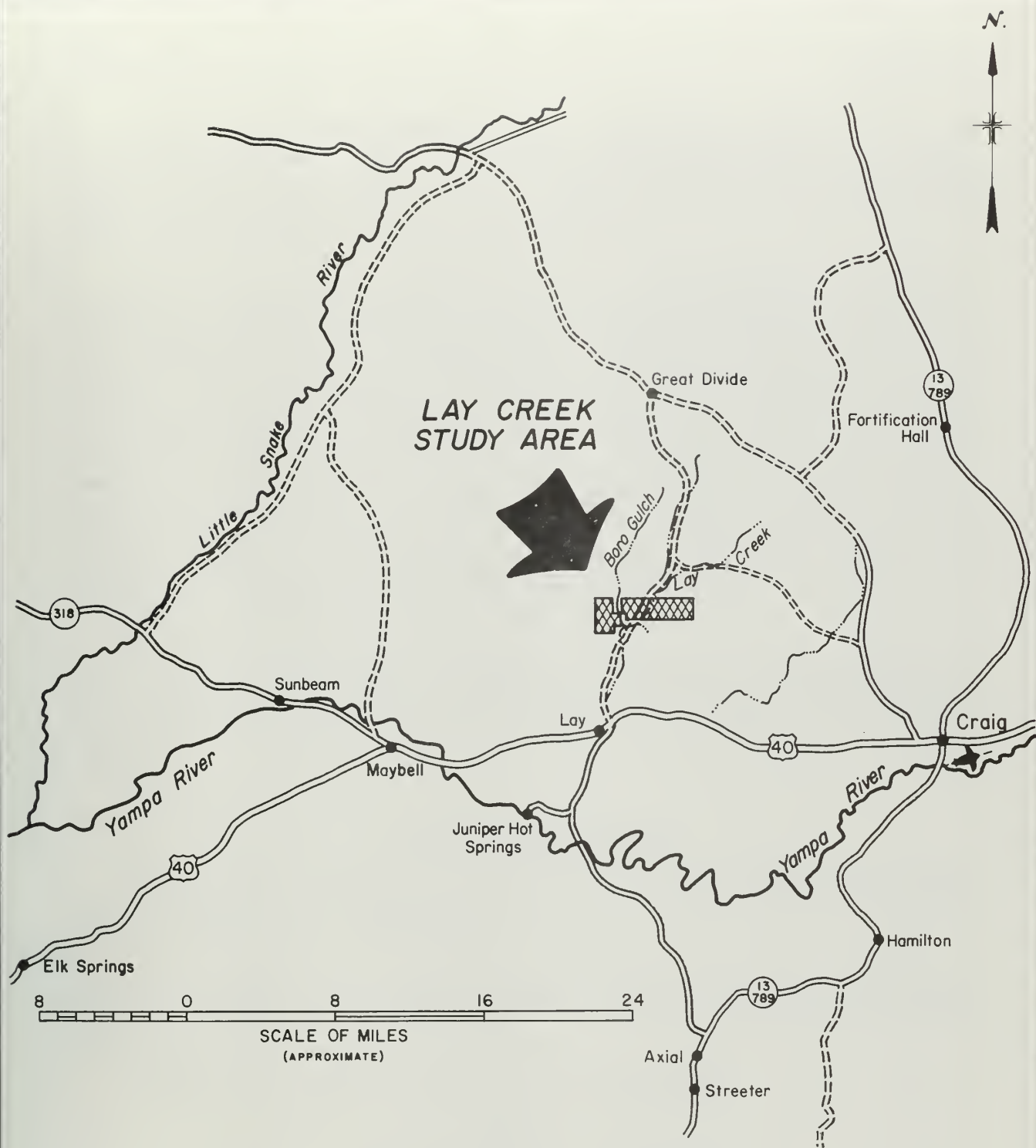
The site lies approximately 6 miles north of Lay, Colo., along a main county road. Elevations range from 6,400 to 7,000 feet above sea level. The main surface drainage is via Lay Creek and its tributary, Bord Gulch. The following photograph taken in the study area illustrates the local terrain.



View looking west across Lay Creek showing the alluvial bottoms and sloping mesa lands.

Historical Perspective

The early European explorers found northwestern Colorado, including the Lay Creek area, occupied by the Ute Indians. The first historic exploration of the area was by the Dominguez-Escalante Expedition in 1776. This expedition entered northwest Colorado, but only as far north as the White River Valley south of Lay Creek and the Yampa River Valley.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LAY CREEK COAL STUDY
GENERAL LOCATION MAP

FIGURE 1

Following the Dominguez-Escalante expedition, white men entered northwestern Colorado, initially for the fur trapping industry. In 1824, William Ashley, Jim Bridger, Thomas Fitzpatrick, and Milton Sublette came down the Yampa River Valley, and trapping flourished until the early 1840's when the fur trade became unprofitable.

The early explorers described the area as of little use, and it was not until the gold rush days in the late 1850's that settlers began moving into northwestern Colorado. During the early 1860's and 70's, the few scattered settlers in northwestern Colorado did not threaten the Indians' use of their lands. In 1868 the White River Agency was established to educate, civilize, and Christianize the Ute Nation. Following the Meeker Massacre in September 1879, the Indians were removed from northwestern Colorado and the land opened for homesteading. Settlement quickly occurred along the Yampa River including the Lay Creek area. Soon after the homesteaders, cattlemen moved into the area and the cattle industry boomed. In the early 1890's sheep were introduced into the area with the resultant conflicts between cattlemen and sheepmen. These conflicts were resolved, and the livestock industry remains the mainstay of the economy and politics to the present day.

The coal resources of the area were noted early during its settlement. In the early 1900's a commercial coal mine was operated south of Lay, Colo., and in 1907 the Blevins mine on the study site was operated to fill local needs. At the present time no coal is mined near or on Lay Creek.

Land and Mineral Status

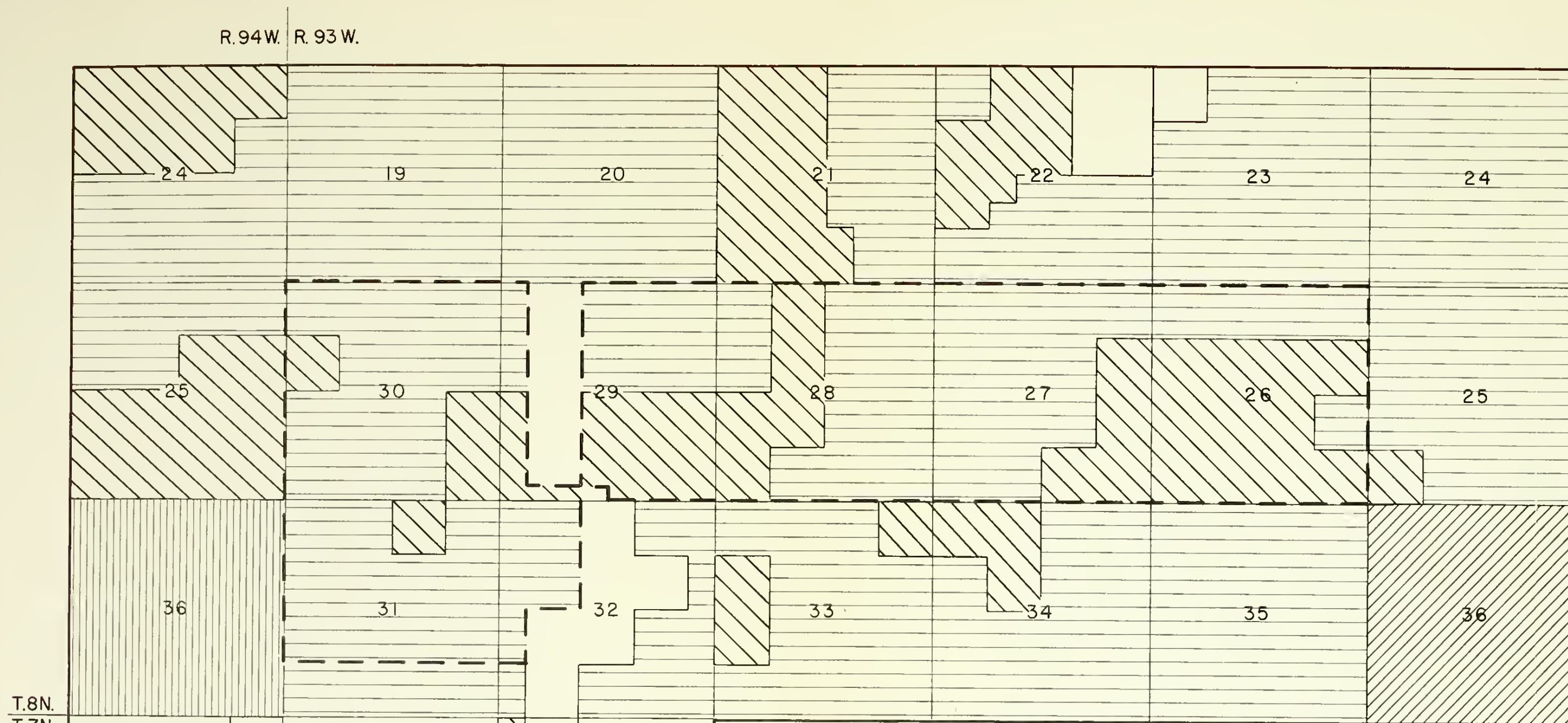
Most of the lands within the study site are in private ownership. Surface ownership is controlled principally by four private ownerships and the Bureau of Land Management.

Mineral rights are controlled by the Federal Government and administered by the Bureau of Land Management. Figure 2 illustrates the land and mineral status of the study area.

Table 1 is a summary of land status by ownership.

Table 1
Surface ownership land status
(acres)

Ownership	Section							Total
	26	27	28	29	30	31	32	
Private	200	480	440	310	510	430	145	2,515
Federal	440	160	200	170	120	40		1,130
Total	640	640	640	480	630	470	145	3,645



EXPLANATION

- Federal Lands - Federal Minerals
- Federal Lands - Non-Federal Minerals
- State Lands - State Minerals
- Private Lands - Federal Minerals
- Private Lands - Private Minerals
- Study Boundary



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LAY CREEK COAL STUDY

LAND AND MINERAL OWNERSHIP

FIGURE 2

CHAPTER II

PHYSICAL PROFILE

Present Land Use

The lands in the Lay Creek study site are an important part of the Lay Creek watershed area. Present land use is principally rangeland utilized by wildlife and livestock. Other than grazing, important uses include cropland; both irrigated and dryland farming; hunting; and other recreation uses, both summer and winter.

Authorized livestock use on the study site is permitted under grazing leases on approximately 1,130 acres administered by the Bureau of Land Management. Land use on private lands includes livestock grazing, cropland, both dryland small grains and alfalfa, and surface- and subsurface-irrigated alfalfa, and meadow grasses for hay

Wildlife use includes habitat for deer, antelope, and small upland game species. The limited recreational use includes hunting in season and some winter sports such as snowmobiling. Access is restricted into much of the area due to private surface ownership, and fees for hunting have become a source of income for many landowners in the area

Climate

General

The Lay Creek study site is situated in the western Colorado semi-arid region. The site climate is highland continental.

Colorado is in the zone of westerly winds aloft which, depending upon the length of their sojourn over the Pacific Ocean, carry varying amounts of moisture.

Thousands of miles from any major sources of moisture, precipitation is generally light in the lower elevations, as large amounts of moisture are drawn off the air masses as they cross major mountain ranges to the west. The air is again cooled as it is lifted orographically over the mountains and gives up much of its available moisture in the form of snow west of the Continental Divide during the winter months. This air during the summer months gives cool temperatures and scattered afternoon thunder showers typical of western Colorado.

Climate for the site is affected by differences in elevation and less directly by the orientation of the mountain ranges and valleys with respect to prevailing air movements.

The rugged topography of western Colorado causes large variations in climate within short distances. The Lay Creek study site lies almost equidistant (14 miles) from the towns of Maybell, Colo., and Craig, Colo., for which long-term climatic data exist. Average annual precipitation data show an increase of 2.3 inches from Maybell (elevation, 5,920 feet) to Craig (elevation, 6,440 feet), a distance of only 28 miles with an increase in elevation of 520 feet.

Craig weather of past years, which constitutes climate, should be an adequate guide to conditions during the next decade in the Lay Creek site. Precipitation values can be expected to run somewhat higher at the site than the values given for Craig in this report because of the difference in elevation.

Temperature

Seasonal mean temperatures for Craig, Colo., are 57° F for the summer (April-September) season and 28° F for the winter (October-March) season. There is a possibility of below freezing temperature in the Craig area year round and a chance of greater than 95° F temperature in the midsummer months of June, July, and August.

Plant response to temperature is indexed by high and low temperatures that stop growth and an optimum temperature for greatest growth. These cardinal temperatures vary with plant species and developmental stage.

Careful selection of revegetation species will need to be made. Daily temperature variations and also diurnal variations may exhibit large ranges that could seriously affect sensitive species during seedling, emergence, transplanting, flowering, and seed dispersal stages.

Growing season

The effective growing season can be approximated by the frost-free period, which is from early May to late September (149 days) and the period of mean monthly temperature greater than 32° F, which is from late March to mid November (237 days).

The large range is possible because of the ability of some plant species to resist a drop in temperature below the freezing level for brief periods without damaging their productive growth potential. This drop below the freezing level is a fairly common occurrence during the summer growing season and should be viewed as an important constraint in species selection.

The ability of certain vegetation species to withstand below freezing temperatures allows a closer approximation of the growing season. Using a 7-day running mean, temperatures (50 percent probability) at Craig have stayed for:

182 days above 40° F, from April 25 to October 24;
212 days above 35° F, from April 10 to November 7; and
239 days above 30° F, from March 26 to November 20.

The period using the 40° F threshold temperature is generally considered to be a better approximation of the effective growing season, as active growth for many temperate plants occurs when the average air temperature remains above 40°. This appears reasonable as it falls within the range of the frost-free period and the period of mean monthly temperature greater than 32° F.

Precipitation

Lay Creek study site is in a semiarid region west of the Continental Divide which receives less than 16 inches of precipitation annually.

The basic mechanisms for producing precipitation in the study site area are (1) large-scale organized storm systems which occur in the winter and spring seasons, (2) orographic lifting which occurs during the same seasons when the prevailing westerly flow aloft is the strongest, and (3) convective thunderstorm activity which is the dominant mechanism during midsummer when large-scale atmospheric circulation is weak but solar insolation and heating are strong.

The precipitation in the region increases from the western part of Colorado to the mountain ranges of the divide as the elevation increases. At three stations in the site area (from west to east, respectively), annual precipitation amounts are Maybell, Colo. (elevation 5,920 feet), 11 inches; Craig, Colo. (elevation, 6,440 feet), 13.3 inches; and Hayden, Colo. (elevation, 6,375 feet), 15.5 inches.

Elevation is the controlling factor as far as differences in the precipitation regimes are concerned. Topographic features of the three stations are comparable, as are the slope and aspect.

Extrapolation of available precipitation data to the study site area yields approximately 14.5 inches annual precipitation.

Monthly precipitation by season for Craig is 7.2 inches in the summer (April-October) and 6.1 inches in the winter (October-March).

Considerable variability of both annual and seasonal precipitation occurs. The greatest total annual precipitation for Craig (1951-75) occurred in 1957 with 18.7 inches; the lowest occurred in 1958 with 7.4 inches.

This extreme difference in year-to-year precipitation causes considerable problems in revegetation efforts. Plants chosen for revegetation must be able to tolerate these extreme conditions.

The inconsistency of precipitation may cause severe setbacks to vegetation as the requirements of moisture change with the plant

developmental stages. For example, plants that germinate in the spring with an ample supply of moisture may face periods in June or July of near drought conditions with little or no rain for weeks that would cripple or kill many plants.

Precipitation intensity during the summer months will rarely have events greater than 1.0 inch. In the years of record (1948-75) there has been an average maximum of 1 day per month with precipitation greater than 1 inch for the months April through December and no events of 1-inch precipitation in the months of January through March.

Water erosion of topsoil should not be a significant problem in reclamation efforts. Although potential is high in the summer months for large convective thunderstorms, cloudburst events rarely occur. At no time in the 28 years of record has there been a precipitation event greater than 2 inches in a single day.

Annual snowfall is 69.1 inches, 40 percent of which falls during January and February. Snow depth is typically a foot or less but can be as great as 2 feet. There is a 76 percent chance of 1 inch or more of snow on the ground from December to March. While this is not a heavy snow cover, it will still provide some protection for vegetation through the midwinter months. There should be sufficient amounts of snow and wind at the site to apply snow management techniques that would increase the snowpack, delay spring melting, and increase soil moisture availability into late spring and summer.

Other climatic elements

Data on wind, solar radiation, and evaporation are lacking at stations in the area of the study site, so a detailed analysis cannot be supported. Some general comments can be made, however. Prevailing wind direction during the winter and spring months is from the west and northwest. Occasional gusting wind in winter can occur, resulting in high drifts and windblown bare spots, depending on topography and protection. Wind conditions during the summer and fall seasons are calmer with wind direction more dependent on topography and mountain-valley wind systems.

Little is known about the winter solar radiation averages and variations for the site; but for the summer months, cloudiness and, therefore, solar radiation is very similar across all of Colorado. On a typical midsummer day, solar radiation total should equal about 60 percent of the extraterrestrial radiation. For June 21 this would equal about 2,300 Btu per square foot per day of solar energy reaching a horizontal surface at the study site.

Maximum evaporation rates occur in midsummer when temperatures are highest. Average annual evaporation (from shallow lakes) at the Lay Creek site is approximately 36 inches.

Physiography, Relief, and Drainage

The Lay Creek study site is located in the southern part of the Wyoming Basin Physiographic Province of the Rocky Mountain Region. The Wyoming Basin covers approximately 40,000 square miles in southern Wyoming and northwestern Colorado. It has maximum east-west and north-south dimensions of approximately 250 miles. Elevations of the plateau surface are generally between 6,300 to 7,100 feet above sea level. The basin is bordered for the most part by abrupt mountain slopes on the north and south. It is indented by long spurs and studded by isolated mountain peaks. Through openings between the Big Horn and Laramie Mountains on the east and the Uinta Mountains on the west, the Wyoming Basin is continuous with the Great Plains and Colorado Plateau Provinces.

The southern part of the basin is characterized as a large rolling prairie, broken up by hogback ridges, cuestas, and steep, eroded escarpments. Mild folding has effected the topography in the area of the study site, and broad areas of mild relief are separated or interrupted by scarps and dissected cuestas. Major land forms include narrow alluvial valleys or creek bottoms, eroded badland areas with steep escarpments, mesas, and gently rolling hills.

The natural drainage system is Lay Creek and its major tributary, Bord Creek. Lay Creek flows south and southwest across the study site and has its confluence with the Yampa River some 12 miles downstream near Maybell, Colo. The Yampa is a major tributary of the Green River drainage.

The topography of the area is rough and rolling and is illustrated in Figure 3 on page 14. Lay Creek bottom lands are narrow, from a quarter to less than a half mile wide, and gently sloping. Hills and footslopes are steep and eroded with a 40-foot vertical escarpment forming the mesa rim. The moderately sloping mesas and cuestas are usually on north exposures while the breaks and badlands have southern exposures. The photographs on the following page illustrate the bottom lands and the badland topography.

Geology

The study area is located on the north flank of the Mud Spring Anticline in the southern part of the Wyoming Basin Physiographic Province of the Rocky Mountain system. The anticlinal axis trends approximately N. 50° W. The study area is characterized by gentle, north sloping mesas and well incised drainages. Elevations within the site range from 6,400 to 7,000 feet.

Regional geology

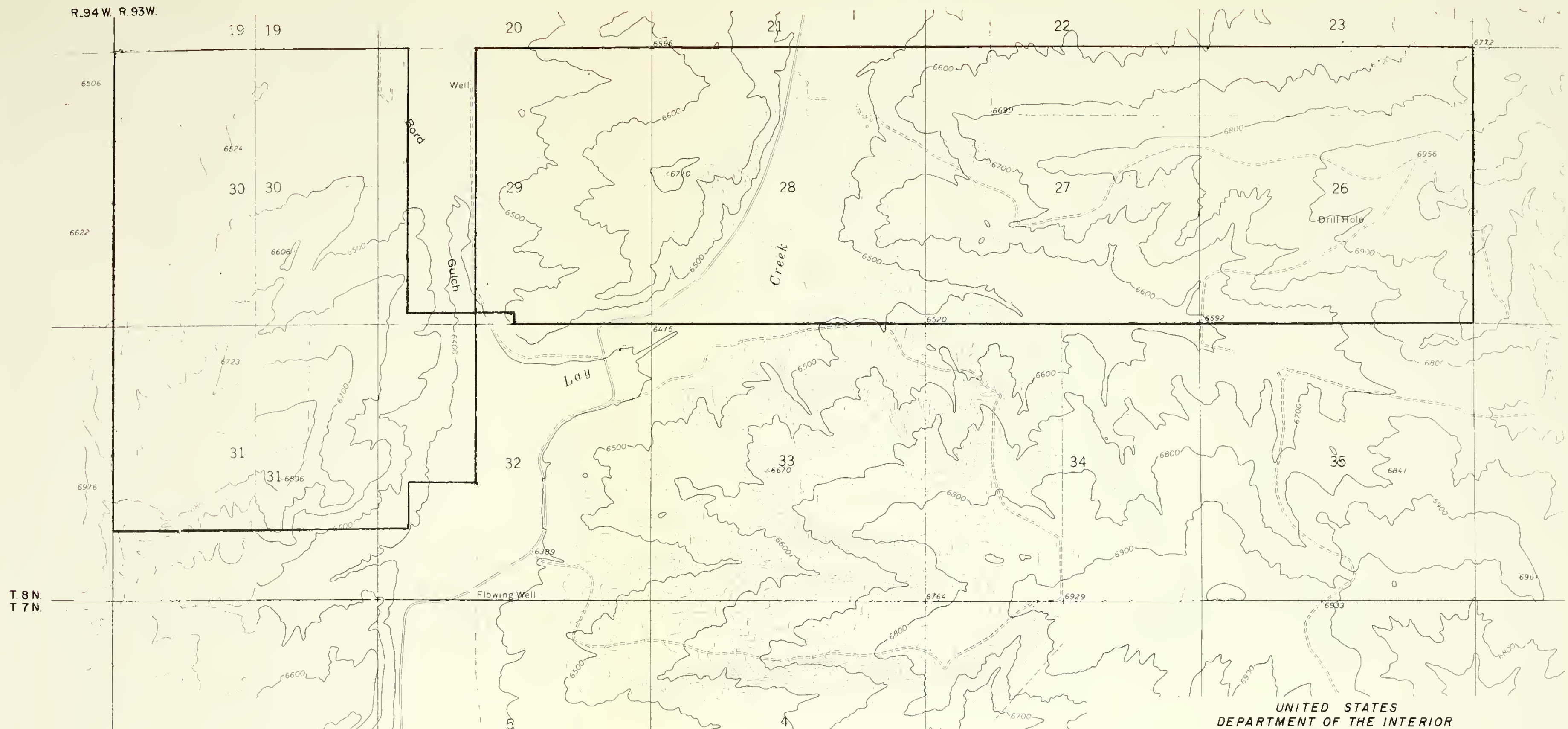
Exposed rocks in the study site are sedimentary in origin and consist almost entirely of Tertiary Age formations. A generalized



Bottom lands in sec. 28.



Badlands east of Lay Creek.



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TOPOGRAPHY
LAY CREEK SITE

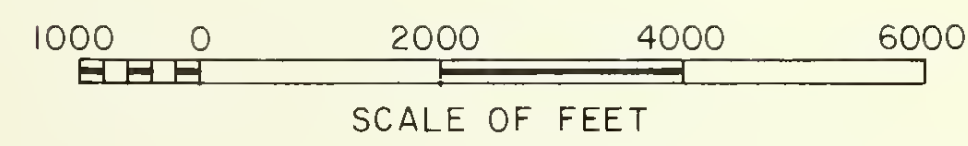


FIGURE 3

stratigraphic section of these sedimentary rocks is shown on Figure 4 (from Plate No. 18, USGS Bulletin 1027). Formation beds within the area strike approximately N. 85° E. and dip gently northward from the axis of the anticline. Older formations of Upper Cretaceous Age underlie the site at depth and are exposed immediately south of the site. The uppermost Cretaceous unit, the Lance Formation, consists of interbedded gray shale; tan to light brown, soft, fine-grained sandstone; and a few coal beds. The formation is about 1,050 to 1,500 feet thick and is succeeded northward by progressively younger rock members.

The Fort Union Formation unconformably overlies the Lance Formation as encountered by drill holes DH-1 through DH-4. The Fort Union Formation consists of interbedded sandstones, siltstones, shale, and coal. The properties of the sandstone varied considerably within each hole, ranging from fine- to medium-grained, poorly to well sorted, and weakly to moderately well cemented. Some intervals were very porous and crumbly. Locally, the Fort Union Shale contains leaf and invertebrate fossil remains. Two of the coal seams found in the upper portion of the formation, the Emerson and Blevins seams, are locally quite thick and are of economic importance. As indicated by drill hole data, the Blevins seam ranges from 10.0 to 14.5 feet thick. Although Bureau of Reclamation drill holes were not deep enough to penetrate the Emerson seam, geologic literature indicates that the seam ranges from approximately 10 to 25 feet thick. The Fort Union Formation is estimated to be as much as 1,400 feet thick.

The Wasatch Formation unconformably overlies the Fort Union Formation and crops out in the northwest quarter of the study area. It consists of brown, coarse-grained sandstone, interbedded with gray and red shale.

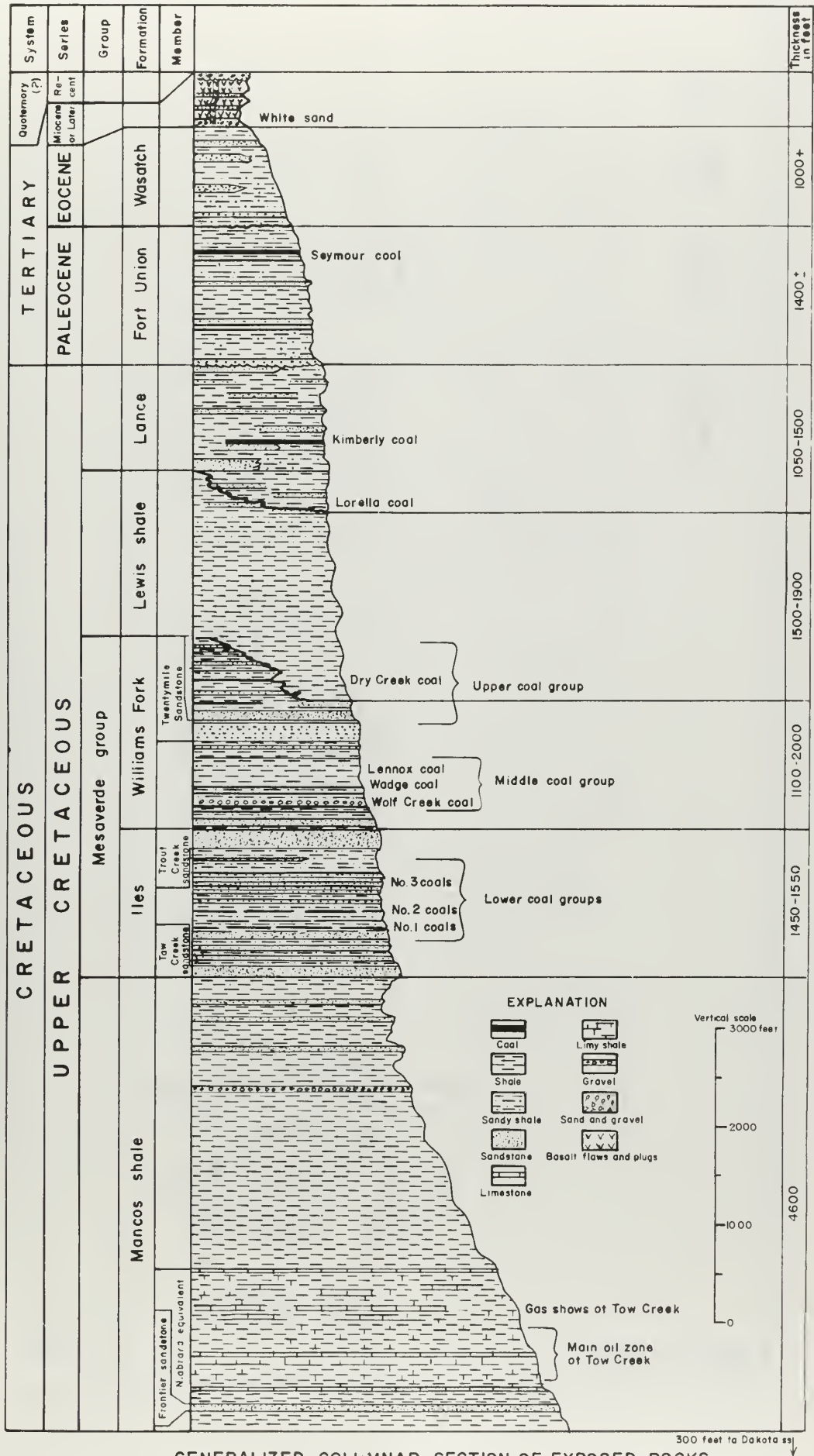
A map showing the geologic formations and drill hole locations within the Lay Creek study site is presented on Figure 5. The map was adapted from E. T. Hancock, USGS Bulletin 757. Figure 6 includes a geologic section of coal beds in the Lay Creek area. Information from USGS drill holes, LSE-1 through LSE-4, was added to clarify the section. For additional information concerning these drill holes, see Appendix A and USGS Open-File Report 78-365, by Michael E. Brownfield.

Geologic investigations

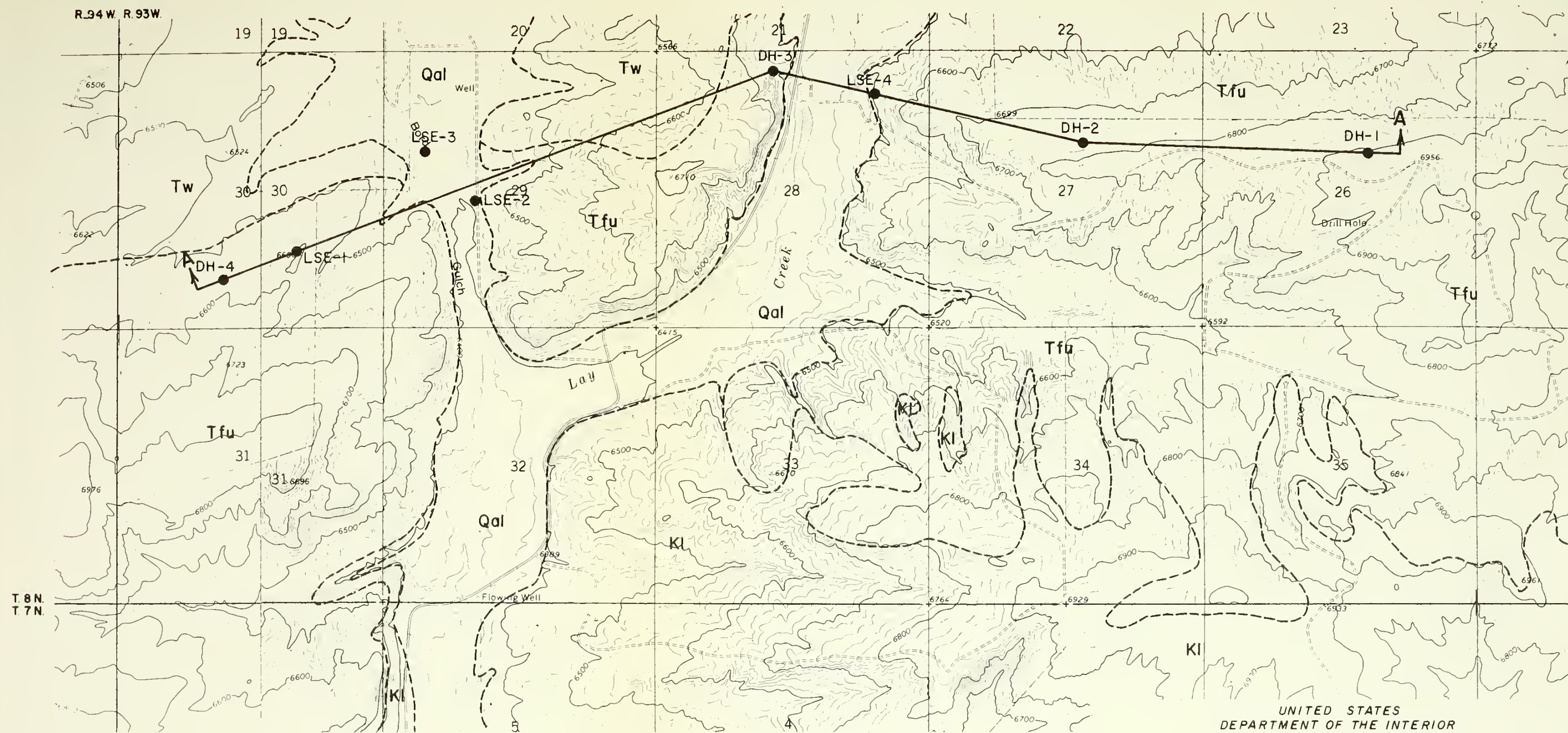
Four Nx-size (3-inch-diameter) core holes, designated DH-1 through DH-4, were drilled at the Lay Creek site by the Bureau of Reclamation. Hole depths ranged from 200.0 to 303.4 feet.

The holes were drilled using a skid-mounted Sprague and Henwood drill using recirculated clear water as the drilling medium. The photograph on page 19 shows the drill rig on the Lay Creek site.

FIGURE 4



GENERALIZED COLUMNAR SECTION OF EXPOSED ROCKS
IN PARTS OF ROUTT AND MOFFAT COUNTIES, COLORADO



EXPLANATION

- Qal Quaternary Alluvium
- Tw Tertiary Wasatch Fm.
- Tfu Tertiary Fort Union Fm.
- Kl Cretaceous Lance Fm.
- - - Approximate geologic contact
- Vertical drill hole
- A — A Geologic cross section

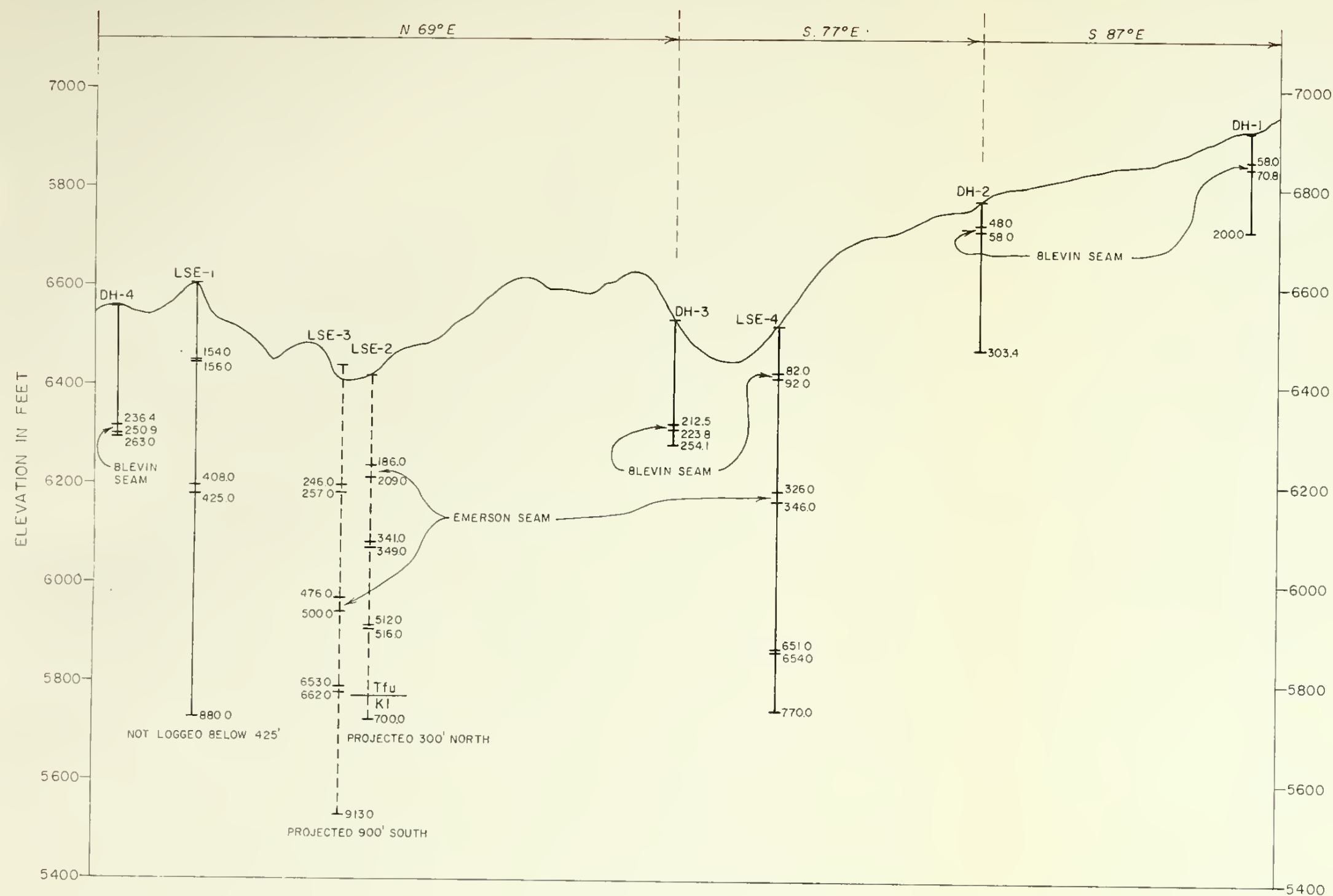
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TOPOGRAPHY

**LAY CREEK SITE
GEOLOGIC MAP**

FIGURE 5

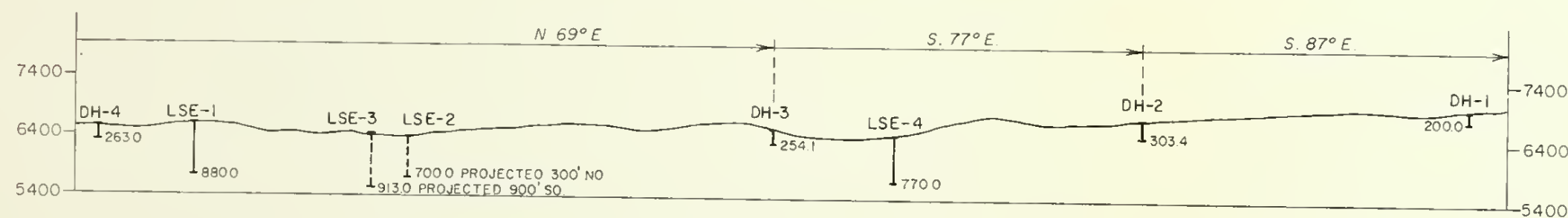
GEOLOGY APPROVED BY Charles A. Smith DATE 4-10-79
REGIONAL GEOLOGIST

X-400-125



SECTION A-A

GEOLOGY APPROVED BY Charles H. Rowik REGIONAL GEOLOGIST DATE 4-10-79



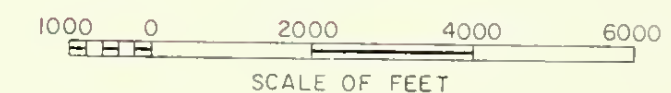
SECTION A-A
NATURAL SCALE

EXPLANATION

- Tfu PORT UNION FORMATION; Interbedded gray, fine to medium grained sandstone, light to dark gray siltstone, gray to black shale, and coal.
- 56.0
62.0 COAL SEAM, with indicated depths of top and bottom of coal seam.
- KI LANCE FORMATION; Interbedded gray shale, tan to light brown, soft, fine-grained sandstone, and a few coal beds.

SYMBOLS

- Tfu
KI Contact, dashed where approximate, queried where inferred.
- DH-1 Exploratory drill hole, dashed where projected to section line.



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LAY CREEK SITE
GEOLOGIC SECTION A-A

FIGURE 6

X-400-126



Cored materials were recovered with wire-line equipment. Temporary Nx casing was used through overburden soil and weathered rock near the surface. Additional casing was required in drill hole DH-2 when very weakly cemented sandstone was encountered at 152.0 feet. Casing was installed to 156.0 feet before drilling resumed. All temporary casing was removed from the holes after drilling was completed.

Upon completion of the drilling, recovered materials were logged by a Bureau of Reclamation geologist. All coal core samples were sealed in plastic bags immediately after removal from the core barrel and were shipped to the Geological Survey in Denver for analysis. The remainder of core samples was shipped to the Bureau of Reclamation Soils Laboratory in Salt Lake City, Utah, for complete soil analysis.

Drill holes DH-1 through DH-3 were temporarily left open for geophysical logging by the Geological Survey. The holes were later sealed at the surface with a grout plug. Hole DH-4 encountered artesian flows and at the request of the Geological Survey was completed as a ground water observation well. There were 264.5 feet of 2-inch PVC pipe, the bottom 80 feet perforated, installed in the hole and grouted at the surface. The drill hole was marked at the surface with a 5-foot steel post to facilitate relocating the site. Representative samples of the major sandstone units, recovered from DH-4, were submitted to the Geological Survey, Water Resources Division, in Denver, for porosity and permeability tests.

The geologic logs of drill holes DH-1 through DH-4 are included in Appendix A on pages 93 through 103.

Engineering geology and physical properties

The shales, siltstones, and sandstones of the Wasatch and Fort Union Formations, which constitute overburden, are weakly cemented to firm except for minor, scattered thin beds containing concretions of hard, well cemented siltstone and sandstone. All excavation would be classed as common, although blasting would facilitate excavation of some horizons.

Coal Resources

Geologic history

During much of Cretaceous Time, the Sand Wash Basin was the site of marine deposition. By Late Cretaceous Time, sands from the west progressively pushed the strand line eastward. The Mesaverde Group and Lance Formation are the result of sedimentation along the margins of regressing and transgressing Cretaceous seas. The Lewis Shale, which overlies the Mesaverde Group, represents a wedge of Marine Shale in the predominantly nonmarine Upper Cretaceous of northwest Colorado. Toward the end of Cretaceous Time, the foreland began to rise and the sea withdrew slowly toward the north and east.

During the deposition of the continental-fluvial Lance Formation, the streams flowed eastward through the basin (Masters, 1961, p. 127). As the foreland continued to rise in the west until it was an active positive area, the Parks Range, to the east of the study area, had risen also. The uplift of the Parks Range resulted in northward diversion of the drainage system. One large river system was established which flowed north, probably from the Sawatch Range (Tweto, 1975, p. 17). Another smaller one flowed east (probably from the Uintas), joining the larger system in the center of the Sand Wash Basin (Colson, 1969, p. 124).

The uplift of the Parks Range led to erosion along the basin edges and deposition of the Fort Union Formation in the central and northern part of the Sand Wash Basin. An extensive basal conglomerate marks the uplift of the Parks Range and the beginning of Paleocene deposition. The broad distribution of sandstones in the lower Fort Union indicates that the early streams were braided and had low sinuosity. The early streams ranged widely across the basin. Increase in sinuosity of Fort Union streams through time brought about initial stabilization of the stream meander belts and caused the formation of extensive flood basins in which coal and thick deposits of silt and clay developed.

Deposition of the Fort Union Formation ended in the early Eocene when renewed tectonic activity caused the uplift of the White River Plateau and Uinta Mountains (Tweto, 1975, p. 3). Again the margins of

the Sand Wash Basin were eroded and coarse sediments of the Wasatch Formation were deposited.

Coal geology

Within the study area, the Fort Union Formation contains three coal zones with economic coal beds. The lower zone contains several coal beds up to 10 feet in thickness. The middle zone contains one very thick coal bed called the Emerson bed. The Emerson bed can be correlated across the entire study area using the drill hole data and surface measurements (see pages 106 and 111 in Appendix A). The coal bed ranges in thickness from about 10 feet at the east end to over 25 feet to the west of the study area. The coal bed averages over 20 feet over most of the study area. The upper coal zone consists of the Blevins bed found in the upper part of the formation. The Blevins bed ranges in thickness from 6.5 feet to 15 feet but generally is over 10 feet thick in the study area (Figure 7). Coals found in the Fort Union Formation are considered to be subbituminous in rank.

Coal resources within the Lay Creek study area were calculated for the upper two coal zones. Both the Emerson and the Blevins coal beds resources have been tabulated in the demonstrated category of geologic assurance. The demonstrated category includes the subdivisions measured and indicated which are based on the nearness of the coal to a measurement of the coal bed and on the geologic evidence and projection.

Measured.--Coal for which estimates of the rank, quality, and quantity have been computed within an area whose limit is within 1/4 mile (0.4 km) of a measurement in a drill hole or surface measurement.

Indicated.--Coal for which estimates of the rank, quality, and quantity have been computed within an area whose inside limit is within 1/4 mile (0.4 km) from the measurement and the outside limit is 3/4 mile (1.2 km) from the measurement.

A summary of the demonstrated coal resources for the Emerson and Blevins coal beds found within the study area is found in Table 2.

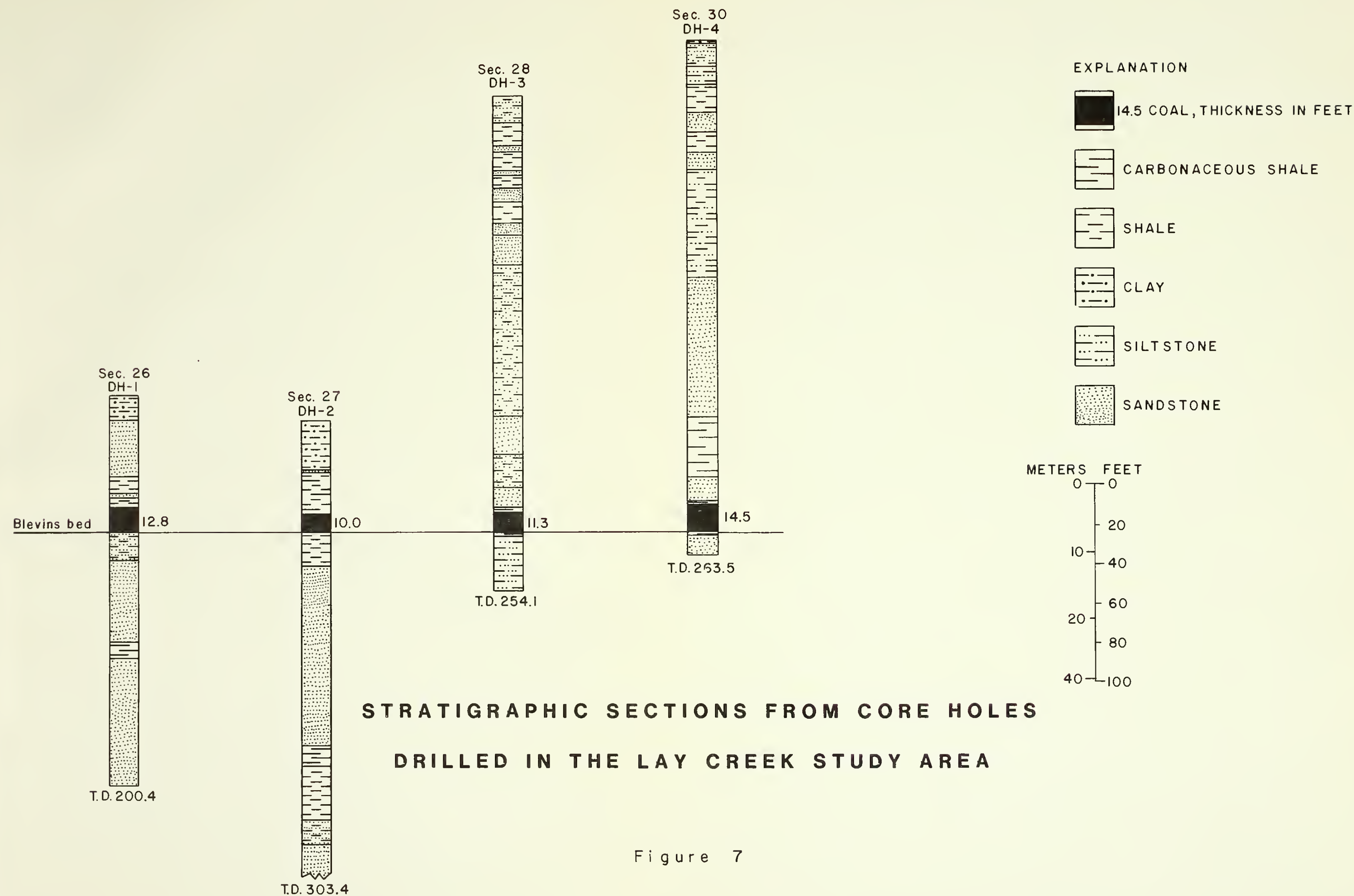


Figure 7

Table 2
Coal resources of the Lay Creek study area

Bed name	Demonstrated resources ^{1/} (tons)
<u>Area I</u>	
Blevins	19,610,000
Emerson	46,920,000
<u>Area II</u>	
Blevins	24,280,000
Emerson	50,860,000

^{1/} Resource estimates are preliminary and subject to revision.

Soil and Overburden Materials and Major Land Categories

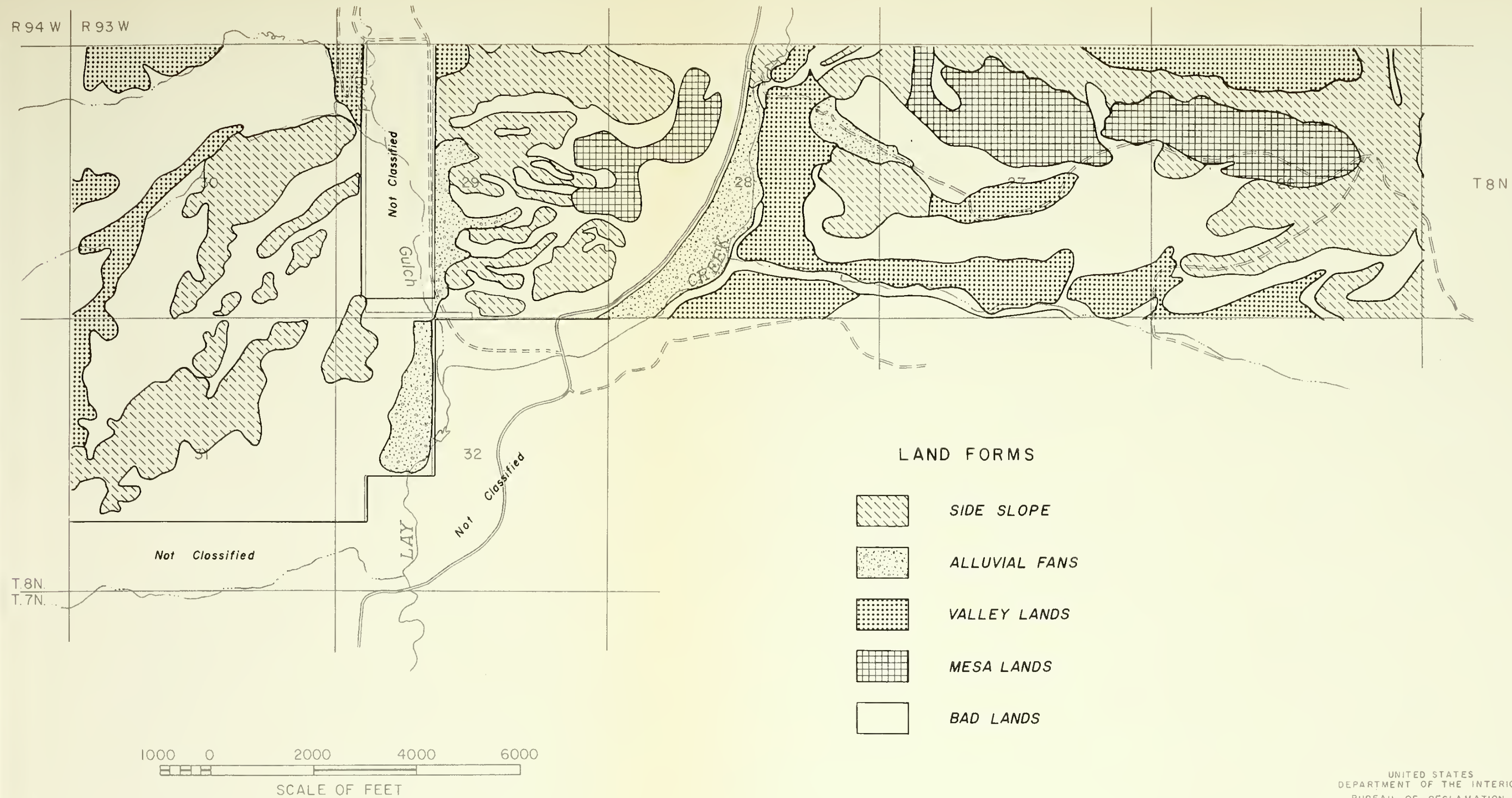
The major land forms identified during the survey included mesas, 310 acres or 8 percent of the total area; valley lands, 515 acres or 14 percent; side slopes, 972 acres or 27 percent; and alluvial fans, 170 acres or 5 percent. These land categories make up 1,967 acres or 54 percent of the study area. Badlands or the rough eroded areas contain 1,668 acres, or 46 percent of the study area. Not included in the above are 10 acres delineated as rights-of-way. Figure 8 shows the location of the land forms.

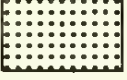
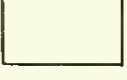
Mesas

There are two types of mesas included in this category. The mesa lands east of Lay Creek (260 acres) are of the cuesta type, while the mesa west of Lay Creek (50 acres) represents an elevated plateau. East of Lay Creek, the upper southern elevations begin at the top of precipitous cliffs or badlands with very little soil. The mesas then slope to the north with single slopes between 10 and 16 percent. The mesa west of Lay Creek has precipitous cliffs on its eastern boundary and slopes to the west and northwest with gradients of between 2 and 10 percent.

Generally, soils on the mesa lands east of Lay Creek are over 120 inches deep. A typical soil profile representative of the eastern mesa lands is described below.

0-6 inches	Brown/dark brown (10YR 4/3) dry, loam, dark brown (10YR 3/3) moist; moderate granular structure; loose, nonsticky, and nonplastic.
6-30 inches	Brown (10YR 5/3) dry, clay loam, brown/dark brown (10YR 4/3)



- LAND FORMS
-  SIDE SLOPE
 -  ALLUVIAL FANS
 -  VALLEY LANDS
 -  MESA LANDS
 -  BAD LANDS

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LAY CREEK COAL STUDY
LAND FORMS

FIGURE 8

	moist; strong subangular blocky structure; hard (dry), firm (moist), slightly sticky, and slightly plastic; many roots. Distinct wavy boundary.
30-36 inches	Same as above except for weak, subangular blocky structures and many lime mycelia.
36-108 inches	Same as 6-30 inches except for massive structure and few lime mycelia. Few root hairs below 5 feet.

The main variations from the typical profile on the eastern mesa areas include loam textures located sporadically in 1- to 2-foot depths in the lower portion of the profile. Also, an occasional soil profile below the 120-inch depth contains some parent material from weathered sandstone, shale, or siltstone.

The mesa soils west of Lay Creek are generally less than 60 inches deep. Surface textures range from loam to clay loam. The colors above 12 inches are brown to dark brown (10YR 4/3), while below this depth the colors are a very pale brown (10YR 7/3). The surface soils have a weak platy to moderately granular structure. They have a loose, nonsticky consistency and are nonplastic. The structure of the soil below the 12-inch depth is strong subangular blocky. It has a hard, firm, and slightly sticky consistency and is slightly plastic. Some roots are found in the 6- to 30-inch depth. These soils are derived from sandstone.

Hydraulic conductivity rates for mesa soils were classed as moderately slow, 0.2 to 0.8 inch per hour. The water-holding capacity is rated as good, ranging between 5 and 8 inches for a 4-foot depth. Internal drainage appears to be slow to medium.

The electrical conductivity (EC) of the mesa soils is usually less than 4 millimhos per centimeter; however, some of the west mesa soils have EC's of over 4 millimhos per centimeter below the 2-foot depth, and some of the east mesa soils have EC's of over 8 millimhos per centimeter below the 3-foot depth.

The mesa land soils are highly suited for use in surface-mined reclamation. The soils are friable clay loams to loam without serious chemical limitations. The mesa soils east of Lay Creek, in particular, are deep and have the greatest potential for reclamation use. Gravel may be encountered at shallow depths in the mesa soils west of Lay Creek, but it should not pose a serious problem in the use of these soils as surfacing material.

Side slopes

These soils have a wide range of characteristics and represent the largest acreage (972) of any suitable land form in the study area. The topography varies from single slopes, gently undulating (5 to 8 percent), to single slopes, moderately steep to steep (10 to 20 percent). Complex slopes (10 to 20 percent) with rolling topography are also found in parts of the east half of the area. The land bodies are mostly noncontiguous with irregular shapes. In some instances they are intercepted by shallow to deep erosion channels.

The soils are generally 36 inches to over 120 inches deep. The textures vary from sandy loam to clay. A typical profile taken on a side slope in sec. 31, T. 8 N., R. 93 W. is described as follows.

0-6 inches	Brown to dark brown (7.5YR 4/4) dry, loam, yellowish-brown (10YR 3/4) moist; fine, weak, platy structure. Loose (dry), slightly sticky, and slightly plastic (moist); indistinct boundary.
6-12 inches	Brown to dark brown (7.5YR 4/4) dry, clay loam, (10YR 3/4) moist; moderate subangular blocky; hard (dry), slightly sticky, and slightly plastic (moist). Many roots, few calcium mottles, residual; distinct wavy boundary.
12-18 inches	Pale brown (10YR 6/3) dry, clay loam, brown (10YR 5/3) moist; massive, hard (dry), sticky and plastic (moist); few small roots, many calcium mottles, residual, distinct wavy boundary.
18-32 inches	Pale brown (10YR 6/3) dry, clay loam, brown, (10YR 6/3) moist; massive hard (dry); sticky and plastic (moist); few small roots, many calcium mottles; about 50 percent float sandstone rock; distinct wavy boundary.
32-40 inches	Greenish-yellow to blue decomposed shale with heavy lime concentrations along vertical fracture joints.

All features described are fairly typical of all side slopeland except for depth. Many hand auger borings have depths greater than 40 inches.

The main variations include an area of clay soils with complex rolling topography found in the northern portions of secs. 26 and 27. Soils shallow to cobble are found sporadically throughout the area. Soils underlain by shale are typical for side slope locations in secs. 31 and 32.

Hydraulic conductivity rates for these soils were classed as moderately slow, 0.2 to 0.8 inch per hour. The water-holding capacity is rated as good, ranging between 5 and 8 inches for a 4-foot depth. Internal drainage appears to be slow to medium.

These lands have no saline or sodic problems and the cation exchange capacity is adequate.

The side slopes are moderately well adapted for use as topsoil in surface-mined reclamation. Most of the soil textures are friable clay loam without adverse chemical limitations. Some soils contain cobble and are shallow. The cobble content, however, will not seriously hamper planting efforts or reduce plant growth. Those areas of clay soils as described above, if used, should preferably be mixed with the other surrounding coarser textures for a more suitable plant media.

Valley lands

The valley lands are located predominantly east of Lay Creek at a midpoint elevation of about 6,450 feet above sea level. Their highest elevation is near 6,800 feet at the upper end of Lay Creek and their lowest is near 6,420 feet. Most of the valley lands in the vicinity of Lay Creek slope to the south and west with single slopes of about 3 percent. Some valley lands are located west of Lay Creek along Bord Creek on the northern and southern borders of the study area. Those on its southern borders have the same slope characteristics as described above; however, they are constricted by the adjoining higher lands and thus occur as a narrower land form. The valley lands on the northern border are disassociated from Lay Creek. They slope to the north and northwest with complex, gently undulating slopes of 5 to 8 percent. Other relatively small scattered areas of valley lands are located in the western portion of the area. These areas have single slopes of less than 8 percent with both southern and northern exposures.

Most of the valley land adjoining Lay Creek and Bord Creek is being farmed, growing small grains and alfalfa both as a dryland and an irrigated crop. The bottom lands are subirrigated and produce both alfalfa and native grasses for hay. Valley lands in the northern portions of sec. 26 and the northern and central portions of sec. 27 are also dry farmed.

Most soils are clay loam in texture, alluvial in origin, and over 120 inches in depth. They are low to moderate in organic matter. The

surface soils are pale brown (10YR 6/3) dry, to dark greyish-brown (10YR 3/2) when wet. Brown (10YR 5/3) when dry is the predominant color of the subsoil and substrata. Soil structure is weakly developed due to its youthfulness. The surface soils have a weak to moderate crumb structure. Subsoils are structureless or weakly developed. They are moderate to highly calcareous, nonsaline, and nonsodic. A few bright rust mottles are at the 42-inch depth on the flatlands near Lay Creek. If required, these lands are well suited for stock piling and for use as a plant growing media.

Alluvial fans

Soils described in this category total 170 acres and are very similar to the valley lands. Their topography includes single slopes from 3 to 6 percent. The largest body occurs west of Lay Creek and east of the county road in sec. 28. Another large area is found in sec. 32 on the southeastern boundary of the classified area. The soils are predominantly clay loams in texture and alluvial in origin. The soils between Lay Creek and the county road have soil depths over 60 inches. The remaining alluvial fan soils in the west half of the area have suitable depths of 6 to 18 inches. The alluvial fan soils predominantly have the same color, structure, and consistency characteristics as discussed for the valley land soils. They also have about the same saline, sodic, hydraulic conductivity, and water-holding capacity properties as have the valley lands.

Soil consistency for the alluvial fan soils when dry is loose at the surface and hard to very hard in the subsoil. The surface soils are slightly sticky to sticky and plastic to very plastic when wet. The hydraulic conductivity rates for these soils are classed as slow to moderately slow, (0.2 to 0.8 inch per hour). The water-holding capacity is rated as good, ranging between 5 to 7.5 inches for a 4-foot soil depth. Internal drainage appears to be slow to medium. The cation exchange capacity ranges from 12 to 30 me/100 gm.

Because of the inherent soil chemical properties, the alluvial soils west of Lay Creek in sec. 32 are only marginally suited for use as stock-piled plant media. Most of soils below 18 inches become increasingly saline and sodic with depth. Electrical conductivity rates ranging between 8 and 31 millimhos per centimeter and exchangeable sodium percentages ranging between 15 and 35 are common in these soils. These rates are excessive and the use of this material as topsoil below the 18-inch depth should be avoided.

Badlands

The badlands are scattered throughout the area. They represent the steep, rocky, eroded cliff areas and the saline-sodic, nearly barren lands which are generally shallow to shale. Most of the steep, eroded badlands have an eastern or southern exposure, as illustrated in the photograph on the following page. The saline-sodic badlands basically slope to the north and northwest. Their single slopes vary from 2 to 15

percent. Complex slopes with slightly rolling topography are found in the northern portion of the badland area. These lands are part of the Bord Gulch drainage, which is a tributary of Lay Creek.



Badlands of Lay Creek site.

The steep rock cliff areas, as their name implies, have little to no soil mantle. As they descend from their highest elevation to their lowest position, some irregular small plateaus with a thin soil layer may occur. These areas were too small to delineate.

The saline-sodic soils vary from about 1 to over 20 feet in depth. These soils are predominantly clay (shale) throughout. They are structureless and massive and have a yellowish-brown (10YR 5/4) color when dry to a dark yellowish-brown (10YR 4/4) color when wet. The surface 0 to 6 inches are generally a clay loam texture, and at times a clay loam strata may be found within the upper 20-foot depth with basically the same soil colors as described above. The main variations within the above are shallower soil profiles with more clay loam and less clay.

The electrical conductivity values for the saline-sodic badlands below a 2-foot depth are excessive, ranging between 6.0 and 31.5. The exchangeable sodium percentage (ESP) rates for the depths below 3 feet are between 15 and 25 percent. These lands support little if any vegetation.

The badlands are not suitable for topsoil use in surface-mined reclamation. The soils of the precipitous cliffs are too shallow and the saline-sodic lands are too saline and sodic to support good plant growth.

Land Suitability Survey, Purpose, and Specifications

The purpose of the land suitability survey was to evaluate and classify lands in the study area as to their relative suitability as a source material for plant growing media. The classification also recognizes the ease of stripping, stockpiling, and redistribution as factors contributing to the suitability of the land for reclamation of the strip-mined areas.

Specifications were developed to characterize four land suitability classes for the Lay Creek study site. The classification describes and ranks three classes of land, or soils bodies, suitable for strippable, stockpiled plant media and one class as unsuitable. The suitability class numbers 1, 2, and 3 correspond closely with the Bureau of Reclamation's arable land classes developed for irrigation development. Class 6 denotes land areas unsuitable for stripping for plant growing media.

Parameters used to develop the suitability classes included soil physical characteristics such as texture, development, permeability, and depth. Soil chemical parameters included salinity, sodicity, organic matter content, and any discernible toxic elements that restrict plant growth. Other considerations include slope, erodibility, terrain limitations, surface rock, and bedrock exposures. The specifications are presented in Table 3.

Description of Land Suitability Classes

Class 1

Class 1 land areas represent the best source of strippable planting media. If not surface mined, class 1 lands could become a borrow area source for plant media.

Class 2

Class 2 land areas have slight limitations and are therefore slightly less suitable for planting media. The principal limiting factor is usually soil depth with all other physical characteristics equal to class 1 lands. Without considering depth, class 2 lands may also be of lower quality due to high salt content, lower water-holding capacity, excessive or restricted permeability, or moderate erosion susceptibility. They may also be more difficult and expensive to strip, stockpile, and manage.

Class 3

Class 3 lands have deficiencies singularly or in combination that restrict their suitability as planting media. They are usually shallow, steep, and limited in size.

Table 3
Land classification specifications^{1/}
Suitability of surface materials for revegetation of surface-mined areas
Bureau of Land Management-Bureau of Reclamation cooperative program

	Class 1	Class 2	Class 3	Class 6 ^{2/}
Soils ^{3/}				
Texture	Loam to light clay	Sandy loam to clay	Fine sand to heavy clay	
Available water-holding capacity	>1.75 inches per foot	>1.0 inch per foot	>0.75 inch per foot	
Permeability	Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion.	Slightly excessive for medium textures and restrictive for fine textures.	Excessive to the extent that special consideration should be given to depth of replacement media on slopes of re-shaped spoil banks.	
Salinity	<4 millimhos	<8 millimhos	<12 millimhos	
Sodicity	<10 ESP ^{4/}	<10 ESP ^{4/}	<15 ESP ^{4/}	
Erodibility	Subject to slight erosion.	Susceptible to moderate erosion.	Susceptible to severe erosion but can be controlled with proper management practices.	
Depth	42+ inches of usable and strippable material.	>18 inches of usable and strippable material.	>8 inches of usable and strippable material. ^{5/}	
Topography ^{6/}				
Slope	<10 percent	<20 percent	<25 percent	
Surface rocks	<5 percent	<5 percent	<10 percent	
Bedrock outcrop	Will not affect stripping or quantity of suitable material.	Will not affect stripping or quantity of suitable material.	Numerous enough to reduce quantity of suitable material appreciably and make stripping expensive.	

Drainage^{7/}

- ^{1/} Specifications are based on rainfed conditions or a minimum of irrigation for starting plantings and maintenance through dry periods.
- ^{2/} All areas not meeting the minimum requirements for classes 1, 2, or 3. These lands are unsuited as a source of material (topsoil) for revegetation.
- ^{3/} Pertains to undisturbed soil and to minimum depth (1.0 foot) of soil redistributed over unconsolidated cast overburden.
- ^{4/} Exchangeable sodium percentage.
- ^{5/} The minimum strippable depth is considered to be 6 inches.
- ^{6/} Topographic factors considered are related primarily to stripping operations.
- ^{7/} Because of land alterations by surface mining, present drainage conditions, excepting the permeability of the material, are not a factor in the classification.

Class 6

Class 6 lands are not suitable as plant growing media. This includes the steep, eroded, and shallow badlands. Their soil chemical properties may also make them unsuitable as a planting media.

Procedures

The study site was evaluated for plant growth media suitability utilizing the specifications as described above. The soil physical and chemical characteristics, topography, and drainage for each major land form were examined in sufficient detail to determine its class and extent. The field delineations were confirmed by the laboratory data from samples collected and analyzed for the typical soil profiles described during the study and the deep power auger holes. The land classes or mapping units were delineated in the field on base maps with a scale of 1 to 4800. A sample base map is presented in Figure 9. The mapping symbols or legend developed for the land classification is shown in Figure 10.

The soil investigations were accomplished using a truck-mounted, 18-inch power auger (Texoma) with a depth capacity of 25 feet. Soil borings were made to various depths, depending on the depth to geologic material and/or the drilling characteristics of the subsoil materials. Additional soil borings were made with a 3.25-inch hand auger where necessary to give adequate data for delineating soil boundaries.

There were 16 power auger holes dug utilizing the Texoma auger. In addition, 47 hand auger borings were made. Three typical soil profile pits were dug using the Texoma auger. These pits were excavated to approximately 4.5 feet long by 1.5 feet wide and 5 feet deep. Genetic soil horizons were observed and data collected to describe soils of the various land classes. These data included soil color, texture, structure, and consistency. Soil samples for laboratory analyses from each horizon or significant texture break were collected.

Laboratory methods and procedures used in the screening tests for soil samples are defined in Bureau of Reclamation Instructions, Series 510, Part 117, "Laboratory Procedures;" the U.S. Department of Agriculture Handbook 60; and Part 2, Agronomy 9 "Methods of Soil Analysis." Screening tests were made on 118 samples from 16 Texoma borings and 48 samples from 13 selected hand auger borings. A complete soil analysis was run on 15 samples from the 3 typical soil profiles. The results of these analyses are presented in Appendix C of this report.

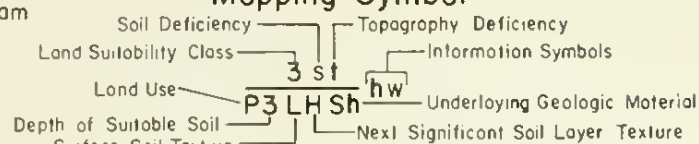
Summary of land classification

A total of 3,645 acres was mapped at the Lay Creek study site. This included 1,133 acres delineated as class 1, representing 31 percent of the total area. The class 1 lands are located throughout the area. They are about equally divided among the mesa, valley, and side slope areas. The valley lands which include the alluvial farmland areas have

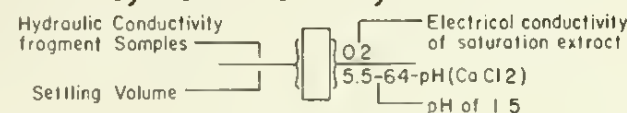
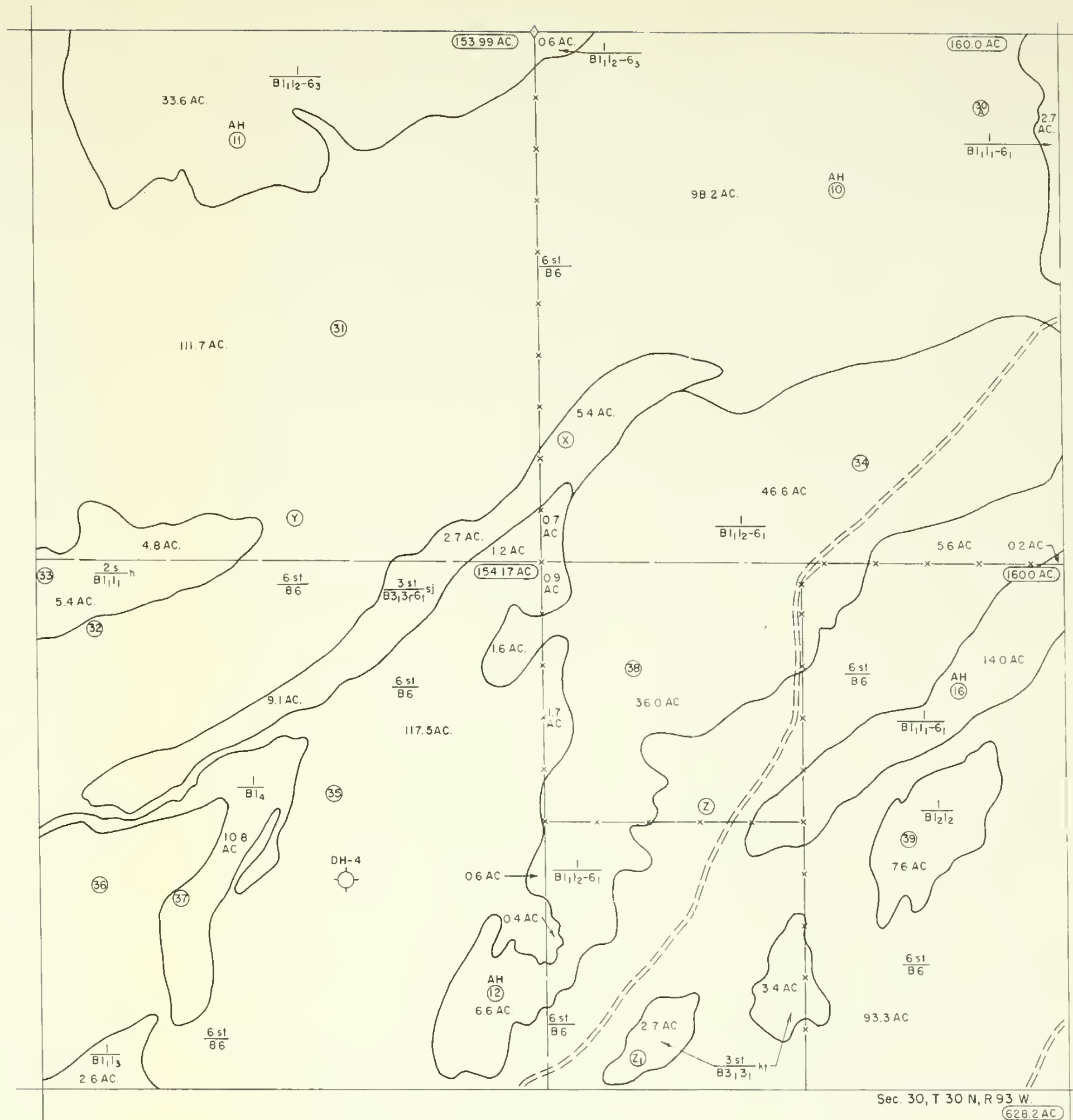
Long Use

Cb	Cobble	C—Irrigated cultivated
Gr	Gravel	P—Irrigated grassland
S	Sand	L—Nonirrigated cultivated
LS	Laamy Sand	G—Nonirrigated grassland
SL	Sondy Laam	8—Brush or timber
L	Laom	H—Suburban or hamestead
SiL	Silt Laam	I—Idle

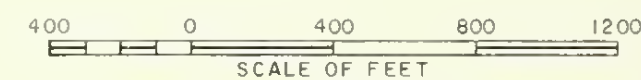
Mopping Symbol



Key to Laboratory Determination

[illegible]

Sec. 30, T 30 N, R 93 W. 628.2 AC



UNITED STATES
Department of the Interior
Bureau of Reclamation

LAY CREEK SITE EMRIA PROJECT
LAND CLASSIFICATION

Classified by: P. Taylor Planimetered by J.K. Jibson

Date Dec 19 78 Photo No. DUE-2JJ-194

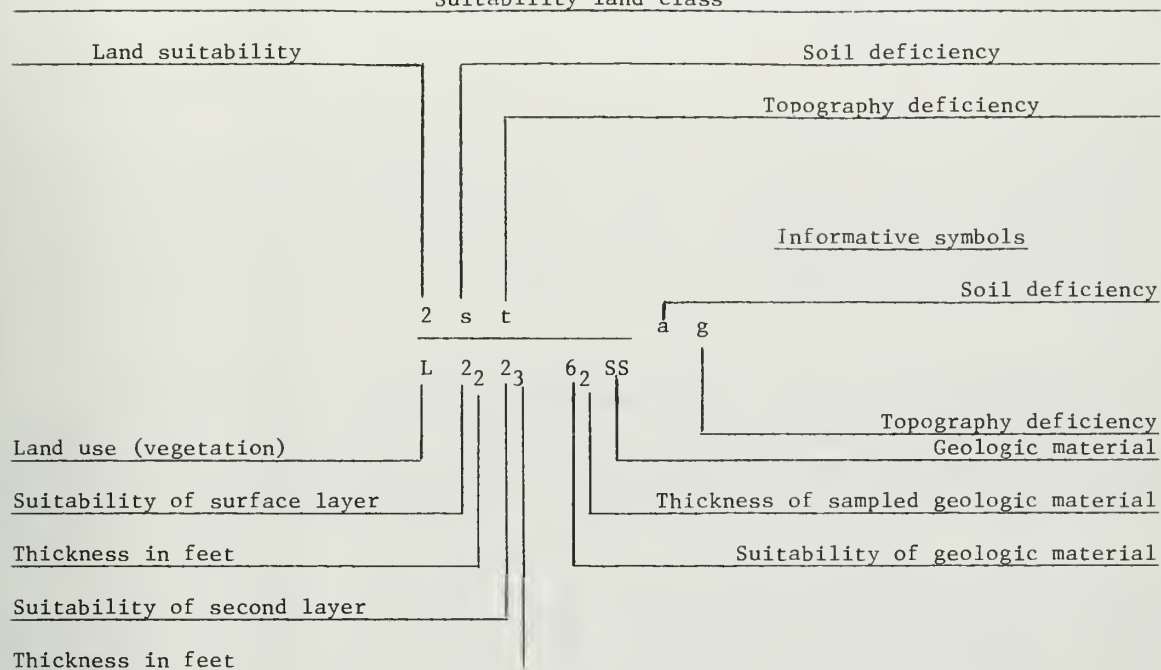
Sec. 30 T. 8N R. 93W

Salt Lake City, Utah

4th Section									Total Suitable	6	R.O.W	Other	Grand Total
	1	2	3	Total	1	2	3	Total					
NE	50.1		5.4	55.5					55.5	104.5			160.0
NW	33.6	4.8	2.7	41.1					41.1	112.9			154.0
SW	22.2	5.4	9.1	36.7					36.7	117.5			154.2
SE	57.6		6.1	63.7					63.7	96.3			160.0
TOTAL	163.5	10.3	23.3	197.0					197.0	431.3			628.2

FIGURE 9

Figure 10
Mapping symbol
Suitability land class



Land suitability class

1	Good
2	Fair
3	Poor
6	Unsuitable
Subclass deficiency	
s	Soil
t	Topography
d	Drainage
Underlying geologic material	
SS	Sandstone
Sh	Shale
Ms	Mudstone
Land use (vegetation)	
B	Brush
C	Irrigated cultivated
I	Idle
L	Nonirrigated cultivated
P	Irrigated pasture

Informative symbols

Salinity		
a	Class 2	>4 millimhos
	Class 3	>8 millimhos
Sodicity		
s	Class 2	>10 ESP
	Class 3	>15 ESP
Topography		
g		>10 percent slope
j		moderately rolling
Soil		
h		Fine texture
k	Shallow depth to gravel/cobble	
r	Surface rock	
v	Coarse texture	

the largest acreage. The predominant soil texture for class 1 land ranges from loam to friable clay loam. They are essentially free from harmful accumulations of soluble salts including sodium within the depth limits established for the class. They are moderately permeable and easily handled.

Class 2 lands represent 14 percent of the total area or 494 acres. They are scattered throughout the site. Subclass 2s (fine-textured soils) predominates and totals 334 acres. Subclass 2s, shallow soils, represents a small area of about 21 acres. Subclass 2st, rocky soil and steep slopes, is scattered in small tracts throughout the study site and totals 139 acres.

Class 3 lands are located predominantly in the northwestern part of the study area and represent approximately 340 acres or 9 percent of the study area. The class 3 lands were delineated as subclass 3s and 3st. Subclass 3s lands usually have a rocky profile and limited soil depth. Subclass 3st lands have fine soil textures and a rolling topography that limit their suitability for stripping.

Class 6 lands represent 46 percent of the area and are scattered throughout the area. They are usually defined in large contiguous blocks and represent the steep, broken, and rocky land areas. They have shallow soils or are barren sandstone and shale outcrops unsuitable as strippable material for stockpiling as topsoil.

These land classes are located as shown in Figure 11 and are tabulated by land class in Table 4.

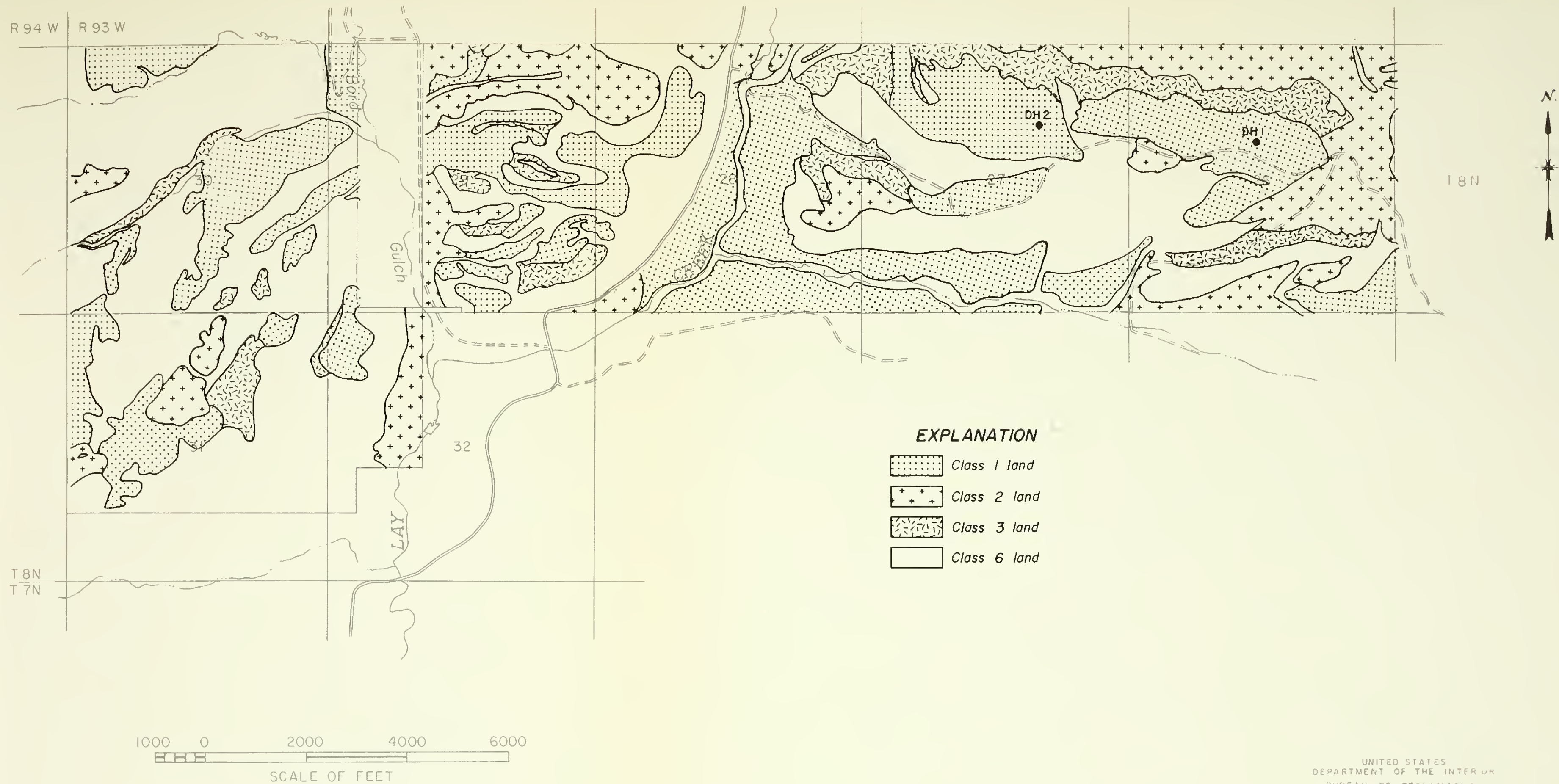
Table 4
Acreage summary by land class

Section	Land class					Right- of-way	Total
	1	2	3	Subtotal	6		
26	155	254	79	488	152		640
27	280	24	72	376	264		640
28	285	72	33	390	241	9	640
29	143	71	77	291	189	1	481
30	164	10	23	197	431		628
31	89	37	33	159	313		472
32	17	26	23	66	78		144
Total	1,133	494	340	1,967	1,668	10	3,645

Table 5 is a summary of land class and subclass characteristics. A tabulation of the Lay Creek land classification by section and subclass is presented in Table 6.

Description of overburden material

Overburden material overlying the strippable coal at the Lay Creek study site includes two geologic formations--the Wasatch and Fort Union. The Fort Union Formation consists of interbedded sandstone, shale, and



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LAY CREEK COAL STUDY
LAND CLASS

FIGURE 11

Table 5
Land class and major subclass characteristics
Lay Creek Federal Coal Management Program study site

Land classes and subclasses	Approximate acres	Major deficiencies		Important soil and land characteristics	Suitability, stockpiling, placement, and management characteristics
		Chemical	Physical		
All classes				Most soil overburden can be stripped easily. Topography will not hinder reclamation, except on class 6st.	Strip, transport, and stockpile carefully to prevent unplanned mixing. Mix soils carefully as necessary to improve poorer soils. Prevent poorer soils from contaminating better soils. Protect from erosion during and after stockpiling and after revegetation. Protect revegetated areas from grazing until revegetation is well established.
Class 1	1,133	None	None	Soils are deep, have good permeability, adequate water-holding capacity, are medium textured, and are nonacidic and nonsodic.	These lands are best source of planting media. No special management required.
2s _v	11	None	Coarse texture	Soils have moderately coarse textures; vary in depth; have good permeability and adequate water-holding capacity for their class; and no major salt problems.	Lands are a good source of planting media. Manage revegetated areas normally.
2s _h	344	None	Fine texture	Soils have fine textures; vary in depth; adequate permeability and water-holding capacity for their class; and no major saline or sodic problems.	These lands are a good source of planting media. No special management required.
2s _k	42	None	Shallow depth to gravel	Soils have gravel or cobble; vary in depth; good permeability and adequate water-holding capacity for this class; and no salt problems.	These lands are a good source of planting media. No special management required.
2st _v	97	None	Moderate slopes and gravel	Soils are gravelly and occur on moderate slopes; have good permeability and adequate water.	Lands are good source of planting media. The topography may cause management problems.
Subtotal class 2	494				
3s _k	59	None	Shallow depth to gravel	Soils are shallow over gravel. They have good permeability and low water-holding capacity.	Lands are a fair source of planting media. Coarse textures may require special management practices.
3s _h	57	Saline and sodic	Permeability fine texture	Soil is slightly saline and sodic and fine textured. It has low permeability and good water-holding capacity.	Lands are a fair source of planting media. The slow permeability will require special management.
3t _{kg}	84	None	Shallow depth to gravel and moderately steep slope or moderately rolling topography.	Soils are shallow to gravel and 10 to 20 percent slope. They have good permeability and adequate water-holding capacity for this class.	Lands are a fair source of planting media. The gravel and topography will require special management.
3st _{hj}	117	None	Moderately steep slopes; fine texture; moderately rolling topography.	Soils are deep, moderately rolling, 10 to 20 percent slopes; fine textured; slow permeability and good water-holding capacity.	Lands are a fair source of planting media. The slow permeability and slopes require special management or placement.
3st _{sg}	6	Saline and sodic	Shallow to gravel; moderately steep.	Soil is shallow to gravel, slightly saline and sodic, has good permeability and adequate water-holding capacity. They are on moderately steep slopes.	Lands are a poor source of planting media. They could be mixed with better quality soils if available. Some of the poorer quality soils should be buried below the root zone. If used for revegetation, careful management will be required.
3st _{sj}	17	Sodic	Moderately steep; rolling topography.	Soil is medium textured with fine-textured underlying layers; sodic; has slow permeability; good water-holding capacity on moderately steep, moderately rolling topography.	Lands are a poor source of planting media. Some of the poorer quality soil should be buried below the root zone or mixed with better soils. The topography may make stockpiling difficult.
Subtotal class 3	340				
6s	11	None	Shallow depth	Soil is less than 6 inches deep.	These soils are not recommended for planting media. If soil is critically needed for mixing, however, these soils may be mixed with better quality soils taking extreme care in stripping, stockpiling, mixing, and placing. Place unsuitable soils well below root zone.
6sd	5	None	Drainage	Seeps and high water table areas.	
6st	1,652	None	Shallow depth; topography.	Soil is shallow and is located on steep slopes.	
Subtotal class 6	1,668				
Right-of-way	10				
Total	3,645				

Table 6
Land classification
Subclass acreage by section

Subclass	Section							Total	Percent
	26	27	28	29	30	31	32		
1	154.9	279.8	285.3	143.2	163.5	89.0	17.2	1,132.9	31.0
2 _{s_v}			3.2	7.6				10.8	.3
2 _{s_h}	189.3	16.8	38.9	63.0	10.2		25.9	344.1	9.4
2 _{s_k}		7.7	29.2			5.6		42.5	1.2
2 _{st_v}	65.1					31.5		96.6	2.7
3 _{s_k}		11.3	14.3	5.3		27.6		58.5	1.6
3 _{s_h}				36.0			21.5	57.5	1.6
3 _{st_sg}				.3		5.1	1.2	6.6	.2
3 _{st_h}	54.8	52.1						116.9	3.2
3 _{st}	14.3	8.4	18.7	36.0	6.1			83.5	2.3
3 _{st_sj}					17.2			17.2	.5
6 _s	9.3		1.9					11.2	.3
6 _{sd}			4.6					4.6	.1
6 _{st}	142.3	263.9	234.8	188.5	431.2	312.8	78.3	1,651.8	45.3
Right-of-way			9.1	1.1				10.2	.3
Total	640.0	640.0	640.0	481.0	628.2	471.6	144.1	3,644.9	100.0

coal. The overall thickness of the Fort Union ranges from 900 to 1,400 feet thick.

The Wasatch Formation unconformably overlies the Fort Union and is exposed in the northwestern portion of the area. The Wasatch consists of a medium- to coarse-grained sandstone, drab to varicolored siltstone, and carbonaceous shale. The Wasatch Formation is approximately 900 feet thick. No coal beds are found in the Wasatch Formations within the study area.

To facilitate the characterization of the geologic or overburden material at the Lay Creek site, four deep core holes were drilled. Figure 12, on the following three pages, is the drill log for DH-2 and is typical of the information found in the other three holes. The complete drill logs and other information for the drilling program are presented on pages 93 through 103 in Appendix A, Geology, at the end of this report.

Overburden Suitability

To determine overburden or bedrock suitability, samples from the core drill holes were analyzed for their chemical makeup and weathering potential. The complete results of the various studies to determine overburden suitability are presented in Appendix A, Geology; Appendix E, Greenhouse Study; and Appendix F, Weathering Study. These studies were conducted on selected samples from the overburden and from material separating the coal beds, even though the second coal bed was beyond the depth of the core holes drilled for sampling.

The results of the selected physical and chemical properties tested are summarized in the Table 7. The weathering tests were conducted on selected sandstone, shale, and siltstone samples from the four core drill holes and included an accelerated laboratory weathering cycle of wetting and thawing, drying, wetting, and freezing. Additional outdoor exposure tests were started on June 8, 1979, and completed June 8, 1980. The results of these tests and any correlation between this type of weathering and the accelerated laboratory weathering conditions are included in Appendix F, Weathering Studies.

Results of the weathering tests indicate that half of the sandstone material would be considered as suitable for plant growing media, that the shale material ranges from limited suitability to suitable, while the siltstone material is suitable based on this one criteria of weathering or slacking down into plant growing media.

Most of the overburden material and the material separating the coal beds were determined unsuitable when considered solely as a plant growing media. This determination is based on chemical data and greenhouse studies. There were 57 chemical analyses made of core samples from the four drill holes. The pH ranged from 7.8 to 10.0, the exchangeable sodium percentage from 0.9 to 44.0, the electrical conductivity ($EC \times 10^3$ @ $25^\circ C$) ranges from a low of 0.27 to a high reading of 8.62 millimhos/cm., and the sodium adsorption ratio from 0.2 to 35.0. Many

GEOLOGIC LOG OF DRILL HOLE

FIGURE 12

SHEET 1 OF 3

FEATURE EMRIA COAL STUDY		PROJECT LAY CREEK SITE		STATE COLORADO				
HOLE No DH-2	LOCATION SW 1/4, NE 1/4, Sec 27, T8N, R93W	GROUND ELEV 6770.0	DIP (ANGLE FROM HORIZ.) 90° DOWN					
BEGUN 11-29-78	COORDS N 1-25-79 E	DEPTH OF OVERBURDEN 25.9	TOTAL DEPTH 303.4	BEARING				
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED		NOT MEASURED	LOGGED BY D. E. GRUNDVIG		LOG REVIEWED BY C. RORVIK			
N WATER LEVELS, CAVING, AND OTHER CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	% CORE RECOVERY	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
	SUITABLE	LIMITED SUITABLE	UNSUITABLE					
NOTE: ALL MEASUREMENTS ARE FROM GROUND SURFACE AND ARE THE SAME AS THOSE USED BY THE DRILLER. HOLE HAS NOT SURVEYED. DEVIATION FROM VERTICAL (IF ANY) IS UNKNOWN. PURPOSE OF HOLE TO OBTAIN SAMPLES FOR DETERMINATION OVERBURDEN PROPERTIES. TO DETERMINE DEPTH AND THICKNESS OF COAT SEAM. DRILLING EQUIPMENT: SKID MOUNTED SPRAGUE AND HENWOOD. DRILLER: G. C. LARSEN, USBR DRILLING METHOD: HOLE HAS ADVANCED WITH NX DIAMOND CORE BIT. CORE RECOVERED WITH HIRE LINE. CASING RECORD: CS CS HOLE SIZE DEPTH DEPTH (INCH) (FT.) (FT.) 4.0 10.0 10.0 4.0 20.0 20.0 4.0 20.0 25.9-156.0							0.0 - 25.9: CLAY APPROX. 80 PCT. MEDIUM PLASTIC FINES AND 20 PCT. FINE SAND. VERY SLIGHT TO NO HCL REACTION. GRAYISH BROWN TO BROWN. (CL) 25.9 - 27.1: SANDSTONE GRAY, FINE TO MEDIUM GRAINED, LIMONITE STAINED POT. THROUGHOUT, MODERATE HCL REACTION. HARD, BREAKS WITH MODERATE HAMMER BLOW. CORE BREAKS ARE CLEAN AND APPROXIMATELY HORIZONTAL. SUSPECT SOME MECHANICAL BREAKAGE. RECOVERED AS 0.3 TO 0.5 FOOT LENGTHS. 27.1 - 48.0: SHALE GRAY TO BLACK, CARBONACEOUS IN PART, LIMONITE STAINED THROUGHOUT. SOMEWHAT SANDY, SLIGHT HCL REACTION. SOFT, EASILY CRUMBLED IN HAND. BREAKS ARE APPROXIMATELY HORIZONTAL. RECOVERED AS FRAGMENTS AND LENGTHS TO 0.4, AVERAGE 0.1 TO 0.3 FEET. 48.0 - 58.0: COAL SAMPLE SUBMITTED TO USGS FOR ANALYSIS. SEE REPORT TEXT FOR DESCRIPTION. 58.0 - 75.0: SHALE DARK GRAY TO BLACK, SANDY, SLIGHT HCL REACTION FIRM, BREAKS WITH LIGHT TO MODERATE MANUAL PRESSURE. MAJORITY OF BREAKS ARE HORIZONTAL AND FREE OF MINERALIZATION. RECOVERED AS LENGTHS FROM 0.1 TO 3.2 FEET. MOST LESS THAN 0.6 FEET. CONTACT WITH SANDSTONE IS GRADATIONAL. 75.0 - 146.9: SANDSTONE SLIGHT TO DARK GRAY, FINE TO MEDIUM GRAINED. PAPER THIN, HORIZONTAL, BLACK SEAMS AND MINOR SHALE SEAMS THROUGHOUT INTERVAL 75.0 - 129.5. SLIGHT HCL REACTION. SOFT TO FIRM. EASILY BROKEN IN HAND. CORE RECOVERED AS FRAGMENTS AND LENGTHS TO 1.0 FEET, MOSTLY 0.5.	
NOTE: ENCOUNTERED WEAKLY CEMENTED SAND AND BECAME STUCK IN HOLE AT 152.0 FT. REALTO OVER WIRE-LINE CASING TO 140.0 AND PULLED WITH LINE CASING. REMOVED PLANNING SHOT FROM CASING. IN TAPER 4.0 INCH CASING TO 156.0 4.0 156.0 156.0-303.4								
EXPLANATION								

GEOLOGIC LOG OF DRILL HOLE

FIGURE 12

SHEET 2 OF 3

FEATURE		PROJECT		STATE														
EMRIA COAL STUDY		LAY CREEK SITE		COLORADO														
HOLE No	LOCATION	GROUND ELEV.		DIP (ANGLE FROM HORIZ)														
DH-2	SW 1/4, NE 1/4, Sec 27, T8N R93W	6770.0		90° DOWN														
BEGUN	COORDS	TOTAL DEPTH		BEARING														
11-29-78	N 1-25-79 E	303.4																
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED		LOGGED BY		LOG REVIEWED BY														
NOT MEASURED		D. E. GRUNDVIG		C. RORVIK														
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	CORE RECOVERY %	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION										
	SUITABLE	LIMITED SUITABILITY	UNSUITABLE															
DRILLING FLUID: CLEAR WATER, RECIRCULATED. DRILLING FLUID LOSSES (PCT.): <table border="1"> <thead> <tr> <th>DEPTH</th> <th>LOSS</th> </tr> </thead> <tbody> <tr> <td>0.0 - 36.0</td> <td>0.0</td> </tr> <tr> <td>36.0-56.0</td> <td>10.0</td> </tr> <tr> <td>56.0-156.0</td> <td>100.0</td> </tr> <tr> <td>156.0-303.4</td> <td>0.0</td> </tr> </tbody> </table> DRILL SITE: ELEVATION 6770. HIGH MOUNTAIN DESERT. SNOW PACKED. MODERATE VEGETAL COVER (SAGEBRUSH, GRASSES) HOLE COMPLETION: AFTER GEOPHYSICAL LOGGING BY USGS. HOLE WAS SEALED WITH GROUT PLUG.	DEPTH	LOSS	0.0 - 36.0	0.0	36.0-56.0	10.0	56.0-156.0	100.0	156.0-303.4	0.0								
DEPTH	LOSS																	
0.0 - 36.0	0.0																	
36.0-56.0	10.0																	
56.0-156.0	100.0																	
156.0-303.4	0.0																	
				6623.1	83	110												
					84	120												
					85	130												
					78	140												
					100	150		146.9 - 166.5: NO RECOVERY RECORDED ON DRILLER'S REPORT AS SAND.										
						160												
				6603.5		170		166.5 - 177.3: SANDSTONE AND SHALE LIGHT TO DARK GRAY, FINE GRAINED. FREQUENT SMALL CONCRETIONS AND MINOR SHALE SEAMS. VERY SLIGHT HCL REACTION. RECOVERED AS FRAGMENTS AND LENGTHS TO 1.1 FEET, MOST LESS THAN 0.4 FEET.										
				6592.7	36	180												
					55	190		177.3 - 204.9: SHALE DARK GRAY TO BLACK, CARBONACEOUS AND SANDY IN PART. SLIGHT HCL REACTION. CRUMBLY, EASILY BROKEN IN HAND. RECOVERED AS FRAGMENTS AND LENGTHS TO 1.2 FEET, MOSTLY LESS THAN 0.6 FEET.										
					72	200												
					85													
EXPLANATION																		

GEOLOGIC LOG OF DRILL HOLE

FIGURE 12

SHEET 3 OF 3

FEATURE		EMRIA COAL STUDY		PROJECT		LAY CREEK SITE		STATE		COLORADO	
HOLE No	LOCATION	SW 1/4, NE 1/4, Sec 27, T8N, R23W		GROUND ELEV		6770.0		DIP (ANGLE FROM HORIZ.)		90° DOWN	
BEGUN	FINISHED	11-29-78		1-25-79		DEPTH OF OVERBURDEN		25.9		TOTAL DEPTH	
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED		NOT MEASURED		LOGGED BY		D. E. CRUNDVIG		LOG REVIEWED BY		C. RORVIK	
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	CORE RECOVERY %	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION			
	SUITABLE	LIMITED SUITABILITY	UNSUITABLE								
				6565.1	85			204.9 - 217.5: SANDSTONE AND SHALE LIGHT TO DARK GRAY, FIRM HORIZONS AND LENSES OF SHALEY, FINE GRAINED SANDSTONE AND SANDY SHALE. DARK SPLOCHES AND THIN SHALE SEAMS THROUGHOUT. SLIGHT HCL REACTION. MOST BREAKS HORIZONTAL. CORE CAN BE BROKEN WITH MODERATE MANUAL PRESSURE. CORE RECOVERED AS FRAGMENTS AND LENGTHS TO 1.2 FEET, MOSTLY LESS THAN 0.6 FEET. 217.5 - 303.4: SANDSTONE LIGHT TO DARK GRAY, SLIGHT HCL REACTION. SOFT, CRUMBLY, ALL CORE CAN BE EASILY CRUSHED OR BROKEN IN HAND. MOST CORE BREAKS ARE INCLINED LESS THAN 12 DEGREES TO CORE AXIS. CORE RECOVERED AS SAND. FRAGMENTS, AND LENGTHS TO 3.8 FEET. MOST LESS THAN 1.0 FEET. INTERVAL 252.1 - 263.8 IS MEDIUM GRAINED AND CONTAINS NUMEROUS DARK SPOTS, BLOTCHES, AND INFREQUENT SMALL COAL FRAGMENTS. INTERVAL 271.4 - 303.4 IS SOMEWHAT DARKER AND COARSER GRAINED THAN PREVIOUS INTERVAL AND CONTAINS NUMEROUS PAPER-THIN, BLACK SEAMS OF ORGANIC MATTER INCLINED 12 - 30 DEGREES TO CORE AXIS. STRATIGRAPHY 0.0 - 25.9: QUATERNARY SLOPEWASH 25.9 - 303.4: TERTIARY FORT UNION FM.			
				6552.5	83	210					
					100	220					
					100	230					
					100	240					
					99	250					
					100	260					
					100	270					
					87	280					
					89	290					
					49	300					
EXPLANATION											

Table 7
Physical and chemical properties and suitability

Bureau of Reclamation															
Sample Number	Depth (feet)	Chemical analysis				Texture ^{1/}	Percent break-down ^{2/}	Greenhouse test							
		ESP	SAR	ECx10 ³	pH			Yield	Postharvest chemical analysis				Nutrient deficiency ^{3/}	Suitability	
									ESP	SAR	ECx10 ³	pH			
Surface soils															
DH-1 #1	0 - 0.5	0.9	0.2	0.27	8.0	Sandy loam		2.34	<1.0	1.6	2.0	7.4	P	Suitable	
#2	0.5- 3.5	2.2	.6	.41	8.2	Clay loam		1.54					P	Suitable	
#3	3.5- 7.0	7.7	5.7	.75	8.9	Loam		2.49	4.0	5.8	3.5	7.8	P	Suitable	
#4	7.0- 10.0	6.7	5.1	2.99	8.4	Loam		2.56					P	Suitable	
DH-2 #1	0 - .75	1.2	.3	.53	8.6	Loam		2.02	<1.0	1.1	2.8	6.7	P	Suitable	
#2	0.75- 5.0	7.2	4.9	.56	8.9	Silt loam		2.31					P	Suitable	
#3	5.0- 9.0	16.0	10.0	5.70	8.5	Loam		1.81						Limited	
#4	9.0- 10.0	11.0	8.1	8.62	8.0			2.10						Limited	
DH-3 #1	0 - 2.0	.9	.3	.35	8.4	Clay loam		2.14					P	Suitable	
#2	2.0- 5.0	4.0	2.0	.39	8.6	Clay loam		1.34					P	Suitable	
#3	5.0- 10.0	5.6	5.3	.64	8.8	Clay loam		1.46					P	Suitable	
DH-4 #1	0 - 1.8	2.5	2.4	.62	8.6	Clay		1.60	1.7	2.9	2.5	7.6	P	Suitable	
#2	1.8- 3.0	12.0	10.0	1.82	8.8	Clay loam		1.85					P	Limited	
#3	3.0- 5.0	12.0	12.0	6.29	8.3	Clay loam		1.72						Limited	
#4	5.0- 8.5	11.0	12.0	7.33	8.2	Clay loam		1.44	11.5	13.0	10.2	7.6	P	Limited	
#5	8.5- 13.0	16.0	14.0	3.17	8.5	Clay loam		2.47	12.7	13.2	5.1	7.5	P	Unsuitable	
Overburden															
DH-1a	42.0- 50.6	2.9	.5	1.02	8.2	Silty clay loam	38	2.00					P	Limited	
b	52.5- 58.0	1.4	.4	2.08	7.8	Clay		1.75					P	Limited	
DH-2a	27.1- 48.0	2.1	1.0	1.67	8.3	Silty clay loam		2.37					P	Limited	
b	58.0- 75.0	3.5	.5	.99	8.3	Silt loam		2.66					P	Limited	
c	75.0- 129.5	6.9	.5	1.28	8.4	Sandy loam		1.54					P	Limited	
d	129.5-146.9	6.7	.5	1.02	8.6	Loamy sand	100	1.83					PK	Limited	
e	166.5-177.3	3.3	.6	1.05	8.3	Loam		2.50					P	Limited	
f	177.3-204.5	1.9	1.8	1.45	8.4	Clay	100	1.96					P	Limited	
g	204.5-217.5	5.6	4.6	1.15	8.8	Silt loam		1.91					P	Limited	
h	217.5-252.1	7.5	7.0	1.00	9.5	Sandy loam		1.79					P	Limited	
i	252.1-263.8	6.1	5.4	1.36	8.9	Sandy loam		2.05	4.5	6.3	3.6	7.8	P	Limited	
j	263.8-271.4	7.4	4.7	1.27	9.1	Sandy loam		2.16					P	Limited	
k	271.4-303.4	11.0	2.5	1.62	8.4	Sandy loam		2.04					PK	Limited	
DH-3a	13.6- 25.1	12.0	14.0	1.44	9.4	Silt clay		2.09					P	Unsuitable	
b	25.1- 28.6	16.0	13.0	1.89	9.4	Silt loam		1.91					P	Unsuitable	
c	28.6- 38.7	22.0	15.0	1.46	9.8	Silt clay		1.88					P	Unsuitable	
d	40.5- 47.4	36.0	16.0	1.03	10.0	Clay loam		1.77					P	Unsuitable	
e	47.4- 55.0	37.0	15.0	1.12	9.9	Loam		2.15					P	Unsuitable	
f	55.0- 65.2	35.0	19.0	1.44	9.9	Silty clay loam		2.15					P	Unsuitable	
g	65.2- 71.7	35.0	25.0	1.63	9.8	Clay loam		1.22	31.4	31.3	6.0	8.1	P	Unsuitable	
h	71.7- 86.9	39.0	24.0	1.86	9.9	Sandy loam	100	2.25	27.0	31.9	6.0	7.9	P	Unsuitable	
i	86.9-102.6	32.0	20.0	1.96	9.6	Loam		1.24					P	Unsuitable	
j	102.6-123.9	36.0	15.0	1.43	9.9	Clay loam	100	1.71					P	Unsuitable	
k	123.9-164.1	23.0	22.0	2.74	9.8	Sandy loam		1.16					P	Unsuitable	
l	164.1-184.2	3.6	6.1	1.75	9.1	Loamy sand		2.47	7.1	4.0		7.2	PK	Limited	
m	184.2-200.1	30.0	21.0	1.49	9.5	Clay loam		1.49					P	Unsuitable	
n	200.1-210.9	26.0	17.0	1.76	9.1	Sandy loam		2.09					PK	Unsuitable	
o	225.4-254.1	44.0	35.0	2.10	9.5	Silt loam	61	1.96					P	Unsuitable	
DH-4a	13.0- 22.6	6.1	11.0	1.04	9.4	Clay loam		1.20					P	Limited	
b	22.6- 36.5	27.0	14.0	1.02	9.9	Silty clay loam		1.78					P	Unsuitable	
c	36.5- 47.2	36.0	25.0	1.71	9.8	Clay loam		1.59					P	Unsuitable	
d	47.2- 57.0	39.0	27.0	2.21	9.9	Clay		1.70					P	Unsuitable	
e	57.0- 66.3	40.0	20.0	1.28	10.0	Loam		1.87					P	Unsuitable	
f	66.3- 69.5	37.0	19.0	1.40	9.9	Clay		1.81					P	Unsuitable	
g	69.5- 74.0	37.0	22.0	1.44	9.9	Silty clay loam		1.78					P	Unsuitable	
h	74.0- 82.1	42.0	21.0	1.39	10.0	Clay loam		1.38						Unsuitable	
i	84.8- 92.5	39.0	19.0	1.38	10.0	Clay		1.46	30.3	36.3	5.8	8.1	P	Unsuitable	
j	95.5-111.3	36.0	25.0	1.50	9.7	Silty clay loam	100	1.34						Unsuitable	
k	111.3-120.4	34.0	24.0	1.64	9.9	Silty clay loam		1.65	26.6	27.6	7.3	7.9		Unsuitable	
l	120.4-192.0	39.0	21.0	1.53	9.9	Sandy loam	0	2.39					K	Unsuitable	
m	192.0-223.2	38.0	23.0	1.70	9.8	Silt clay		1.77					P	Unsuitable	

1/ After crushing and grinding for chemical analysis.

2/ Percent breakdown (weathering test) = $\frac{(TW - IW)}{TW} \times 100$ where TW = total specimen weight
IW = weight of original specimen remaining intact after testing.

3/ P = phosphorus; K = potassium; PK = phosphorus and potassium.

of the overburden samples had a high exchangeable sodium percentage, which indicates that if the material high in sodium were not leached or reclaimed, it would be unsuitable for use as a plant medium.

Table 7 is a summary of the suitability of the soils, overburden material, and the material between coal beds. It is not anticipated that revegetation will be accomplished on weathered overburden materials without top dressing with a layer of suitable soil for use as a plant medium.

Careful handling and management must be used during removal, transporting, and placement of bedrock material to minimize contamination of the more suitable plant media materials.

Toxic Materials

Selected chemical analyses and greenhouse studies (See Appendix E) of the soil and overburden material indicate no significant accumulations of toxic elements other than high sodium concentrations.

Drill holes DH-3 and DH-4 both had high exchangeable sodium percentages. Drill hole DH-3 had sodium percentage values ranging from 3.6 to 44 and sodium adsorption ratio (SAR) values of 13 to 35 in the overburden material below 28 feet which caused an unsuitable designation for much of the material.

Drill hole DH-4 in sec. 30 is also high in sodium. Exchangeable sodium percentage values range from 27 to 42, and the SAR values range from 14 to 27; this caused all the overburden material below 24 feet to be placed in an unsuitable category as plant media.

Terrestrial Flora and Range Sites

The vegetation on the Lay Creek study site was mapped into ecological subdivisions or range sites, Figure 13. The range sites were mapped out according to variations of environmental factors and vegetation. Differences in environmental factors, predominantly in climate, soils, and topography result in differences in vegetation (kind, proportion, and production of plants). The present plant community of each range site was sampled and expressed as percent composition as shown in Table 8 for cover and Table 9 for production. Present production is based on clipping vegetative growth of 1 year. The year 1979 was a favorable year for plant growth. The potential plant community of each range site was determined from range site guides and soil survey interpretations developed by the Soil Conservation Service and is expressed as potential composition, Table 8, and potential production, Table 9.

There were 12 range sites identified and mapped within the study site as described on pages 48 through 54. Due to past management of the vegetation, different ecological conditions of range sites were noted. When this occurred the range site was sampled for each condition. Most

Figure 13
Vegetation map by range site

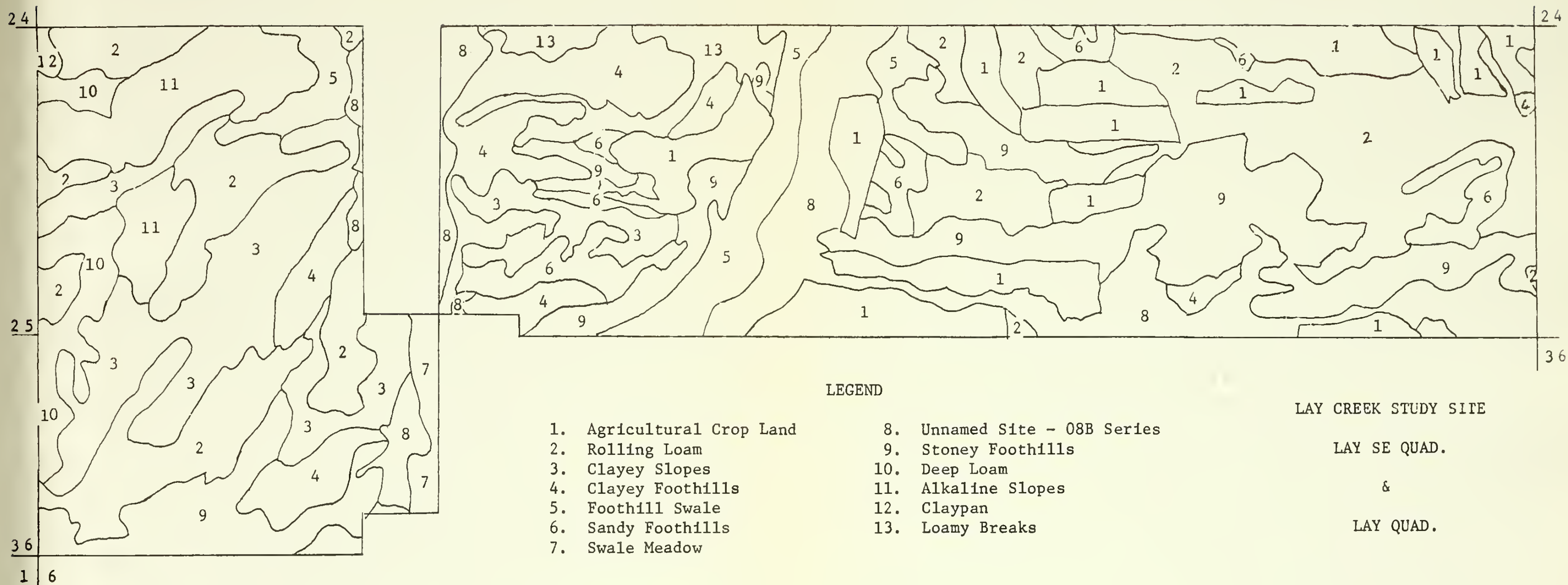


Table 8
Present and potential plant composition^{1/}
Range sites

Species	Clayey slopes				Stony foothills				Rolling loam				Sandy foothills		Foothill swale		Clay pan		Deep loam		Alkaline slopes		Clayey foothills		Swale meadow		Loamy breaks		OBB unnamed		Species	
	Good ^{1/}		Poor ^{2/}		Fair ^{2/}		Poor ^{2/}		Good ^{2/}		Poor ^{2/}		Present	Potential	Present	Potential	Present	Potential	Present	Potential	Present	Potential	Present	Potential	Present	Potential	Present	Potential	Present	Potential		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)																				(13)
Grasses ^{3/}																															Grasses ^{3/}	
Agtr ^{3/}	9.0		5.8		1.0	5	Trace	5	2.2		2.0		11.6	10	0.2	10	9.1		1.1		1.4		15.5				2.5		10.5		Agtr ^{3/}	
Agri	19.5	15	1.3	15	4.0	10	0.4	10	18.8		6.3		2.5	15	19.0	20	1.0	20	9.6		5.0		36.5	35	22.5	30	5.0		7.5		Agri	
Agsm	7.0	5		5		15		15	16.8	15		15	2.9			5					Trace						.9	10	12.0		Agsm	
Agsp										25		25																			Agsp	
Agrop	1.0		.2				1.7		.2		.1				.1	5		10		.7		30			15	Trace	10		15		Agrop	
Brte																											1.6		5.0		Brte	
Carex spp.																									Trace		15	Trace			Carex spp.	
Elci2														5		10															Elci2	
Feov											.3																				Feov	
Juncus spp.																											5				Juncus spp.	
Kocr	.6	5	.6	5			Trace		2.1	5	.1	5	8.0	3				5		5	0.7		.2		0.2	5	1.3	5	.7		Kocr	
Orhy	1.3		Trace		9.0				.8	5		5	.1	10							.6	5	.2	5			.8		35.8		Orhy	
Posa3									1.3																						Posa3	
Poa spp.	.4		0.5						3.1	5	.1	5	10.3	10	Trace	5		5			1.4	5	.1	5	.4	5	.2	5	.7		Poa spp.	
Shvy		5	.4	5	.2	10	1.3	10	.4	5	Trace	5	.2	2	0.1	5	.5		5						.1				3		Shvy	
Stco4	11.0		.7		.5				1.1	5	0.1	5	2.1	10			1.7		.4		.6		.9	5	Trace		3.0				Stco4	
Stle4																															Stle4	
Stipa spp.						10		10				10				1.2		.6										1.0		10		Stipa spp.
PPCC		15		15		10	.1	10									5				.9			5							PPCC	
Forbs																															Forbs	
Allium spp.													Trace															.1			Allium spp.	
Arfe	1.1		.3		.1		.1						0.1						Trace			8.6		Trace				1.0			Arfe	
Trdu																															Trdu	
Aster spp.																															Aster spp.	
Astra	1.7		.8		1.5				11.7		.1										Trace					0.1			.4		Astra	
Cheno									.1				.6											Trace			.3		.7		Cheno	
Ciar4																															Ciar4	
Colli	Trace		Trace		Trace						Trace		.2											Trace							Colli	
Colu	2.6		21.0						10.0		12.5		11.1		6.8		.1		7.3			11.7		Trace	9.0		4.1		2.0		Colu	
Crypt							.4																								Crypt	
Oescu							.7																								Oescu	
Erige									.1						.1					.4									1.0		Erige	
Eriog	.2		Trace						2.3				1.4		.2					Trace							.5				Eriog	
Grsq	1.1						Trace																	Trace			.3		.1		Grsq	
Haplo	.1		17.0								.1										.1			Trace							Haplo	
Hebo	1.8																														Hebo	
Hial			.2																												Hial	
Lare																		.2									.1				Lare	
Lomat							Trace		Trace																			0.3		.1	Lomat	
Luar3			.1				0.3						7.6											Trace							Luar3	
Opuntia spp.	1.4								2.2		.8		.6		Trace		3.5				7.7							1.6		.1	Opuntia spp.	
Peca4	Trace		.1						Trace																			.6			Peca4	
Phho	0.3		2.7				Trace		1.1		5.3		2.3		1.3					0.2											Phho	
Phlo2			.6				Trace		.1				Trace							.7		7.3		Trace	Trace			.1		.6	Phlo2	
Phau5			Trace																												Phau5	
Spco	1.4		0.3		3.5	5	0.2	5	5.0		.4	10	1.8		.2	10	1.0	15	1.9					1.7	5	1.4	10	1.9	7	3.7	Spco	
PPFF	.3	10		10				5		10		10		15		10		15								10		.6	7	.88	PPFF	
Shrubs																															Shrubs	
Amal2																															Amal2	
Artem						10		10																					5		Artem	
Arlo																		35				6.7	10								Arlo	
Ararn																															Ararn	
Artr2	27.0	10		35.0	10	11.0		3.7		14.0		54.2	20.6	10	20.0	10	12.0		76.0	10	.2			15.6	15	7.1		58.0	25	10.0	Artr2	
Atco		10																													Atco	
Atrip		5											.4		.3																Atrip	
Chna																																

1/ Percent by dry weight by range site.
2/ Condition based on percent composition.
3/ Key to symbols and common names may be found in Appendix C, Vegetation.

Table 9
Percent cover and present and potential production^{1/}

	Range sites														
	Clayey slopes		Stony foothills		Rolling loam		Sandy	Foothill	Clay pan	Deep	Alkaline	Clayey	Swale	Loamy	08B
	Good ^{2/}	Poor ^{2/}	Fair ^{2/}	Poor ^{2/}	Good ^{2/}	Poor ^{2/}	foothills	swale		loam	slopes	foothills	meadow	breaks	unnamed
Cover (percent)															
Bare soil	36	31	27	38	17	54	26	34	47	31	62	19	29	32	18
Mulch	23	12	8	6	33	17	28	32	28	29	5	33	19	27	25
Rock	0	3	7	20	2	0	0	0	3	0	0	0	1	1	1
Shrubs	21	43	14	6	22	19	16	6	13	27	23	33	34	23	17
Forbs	8	2	11	5	5	5	1	4	6	5	0	4	8	5	5
Grass	12	9	23	11	21	5	29	24	3	8	10	10	9	12	34
Tree			10	14											
Production (pounds per acre) ^{3/}	791	586	518	1,315	671	993	559	873	864	527	401	614	989	697	569
Potential production (pounds per acre per year)															
Favorable	800		800		1,000		1,200	3,000	800	1,800	800	1,200	2,500	800	
Unfavorable	400		400		500		600	1,000	300	900	400	600	1,500	400	

^{1/} Expressed as pounds per acre for each range site.
^{2/} Condition based on percent composition.
^{3/} Air-dried weight.

of the range sites were within the same ecological condition throughout the study site.

Swale meadow

This site occupies flood plains and terraces of streams. Soils are fine sandy loam to clay loams and may show signs of poor drainage. The variability of the duration and height of the water table causes variation in plant growth.

The site indicates a transition between saline meadows and nonsaline grass-shrub communities. Due to past management practices, saline vegetation now exists. It is comprised of 28 percent greasewood, 27 percent saltbush, 8 percent green rabbitbrush, and 7 percent big sagebrush. These species are normally considered invaders. Western wheatgrass makes up the grass composition, 22 percent, with forbs comprising a minor 6 percent. Annual production was 989 pounds per acre. Vegetation provides 51 percent cover on this site.

Under climax conditions, the vegetation would consist of 90 percent grasses and 10 percent forbs with western wheatgrass being the dominant grass. Under drier conditions, basin wildrye would become noticeable. Potential production would vary between 1,500 and 2,500 pounds per acre annually depending on growing conditions of the year.



Vegetation typical of the swale meadow range site.

Clayey foothills

Soils of this site are deep to moderately deep clay or clay loam. Permeability is slow, but the soils have an excellent water storage capability if cover is sufficient to retard runoff. The high wilting point, however, probably offsets any influence of added water storage on the vegetation. The site is found on rolling benchland and north aspects with slopes less than 12 percent.

Western wheatgrass and streambank wheatgrass dominate the composition with 36 percent and 15 percent, respectively. Big sagebrush and green rabbitbrush make up 29 percent of the composition, giving the area an open brushland appearance. The vegetation on this site provides 47 percent cover.

Potential vegetation for the site would be comprised of approximately 75 percent grass, 20 percent shrubs, and 5 percent forbs. Production would vary between 600 and 1,200 pounds per acre annually depending on growing conditions of the year.

Alkaline slopes

This site is found on upland benches with less than 10 percent slopes. Soils of this site are variable but are characterized by poor soil moisture relationship creating a low site potential.

The present vegetation is predominantly forbs which make up 48 percent of the composition. The major grass specie, western wheatgrass, accounts for 5 percent of the composition with shrubs, such as big sagebrush, rabbitbrush, and horsebrush totaling 33 percent. The site produced 401 pounds per acre, with 62 percent bare soil, resulting in a rather sparse stand of vegetation.

Potential for the site is a brush-grass mixture with each comprising 45 percent of the composition. Total annual production ranges from 400 to 800 pounds per acre.

Deep loam

One area of deep loam is found on the site. It occupies the upper portions of a drainage system with a deep gully dissecting the site. Soils are deep, well drained, and slowly permeable. Available water-holding capacity is high.

This community type has been depleted due to various past pressures exerted on the vegetation. This is indicated by the invasion of big sagebrush which comprises 76 percent of the composition. Grasses and forbs make up approximately 22 percent of the composition. The vegetation provides 40 percent cover for the site.

The site has the potential for moderate to high production rates depending on growth conditions of the year. Annual production during the summer of 1979 was 527 pounds per acre, but the site has the capability of producing 900 to 1,800 pounds per acre indicating the existing problem of the invasion of undesirables.

Clay pan

This subdivision occupies only a small portion in the northwest corner of the study area. This area is delineated from the surrounding areas due to the vegetative restriction of the clay content in the soil. It is level to gently sloping and the subsoil is strongly structured and fine textured. The subsoil tends to restrict water permeability and plant moisture availability due to the high swelling characteristics associated with the clays.

The area supports a wide diversity of shrub species resulting in a low appearing shrub-dominated community. Rubber rabbitbrush and green rabbitbrush have the highest composition accounting for 70 percent of the total annual production of 864 pounds per acre. Streambank wheatgrass is the dominant grass with 9 percent composition. Shrubs make up 13 percent of the total cover with 47 percent bare soil.

Principal grass species, in a climax state, are prairie junegrass, wheatgrasses, and bluegrasses. The site is dominated by alkali sagebrush, with rabbitbrush and saltbush also present. The site is treeless with potential production ranging from 300 to 800 pounds per acre annually.

Loamy breaks

This particular site consists of stony ridges leveling off to gentle east-facing slopes. The degree of slope ranges from 3 to 25 percent; this influences the moisture retention of the soil. The soils are fairly shallow, medium textured, and classified as loam or stony loam. Permeability is moderate; but due to the steepness of the topography, plant moisture efficiency is reduced.

Big sagebrush dominates the site making up 58 percent of the total composition, along with nearly 8 percent green rabbitbrush. Western wheatgrass, streambank wheatgrass, needle-and-thread, and junegrass support the major grass community, making up approximately 12 percent of the composition. Forbs make up 17 percent composition, resulting in 697 pounds of forage produced per acre. The vegetation provides 40 percent ground cover.

The potential production for this site varies from 400 to 800 pounds per acre annually depending on the climatic factors of that particular year. Composition under climax conditions could total as much as 48 percent grasses, 7 percent forbs, and 45 percent shrubs.

Clayey slopes

Topography of this site is steep and hilly with slopes ranging from 15 to 65 percent. The site occupies foothill ridge crests and side slopes with soil varying from moderately deep to shallow. Soils are well drained, have slow permeability, and low available water capacity.

This site was divided into separate study areas based on their condition due to past management practices. The clayey slopes site, which was rated in good condition, is dominated by 27 percent big sagebrush. The grass community comprises nearly 50 percent of the composition with the major grass species being western wheatgrass, streambank wheatgrass, bluebunch wheatgrass, and needle-and-thread grass. Forbs make up nearly 12 percent of the composition.

The other area, which was classified as clayey slopes and rated in poor condition, supports such brush species as big sagebrush, green rabbitbrush, and winterfat to make up 45 percent of the composition. With this increase in brush vegetation, competition between species increased, leaving only 9 percent grasses within this vegetational pattern. The major grass species is streambank wheatgrass followed by western wheatgrass. Forbs production was high, accounting for 43 percent of the production. Vegetative cover is 41 and 54 percent, respectively.

The potential for the clayey slope range site ranges from 400 to 800 pounds per acre annually, depending on growth conditions of the year. The native grasses, including western and bluebunch wheatgrass, junegrass, and squirreltail make up 45 percent of the composition. Big sagebrush, shadscale, and atriplex species would make up the shrub community intermixed with approximately 10 percent forbs.

Foothill swale

The location of this community lays adjacent to the clayey foothills and rolling loam sites. Due to its position, this site receives additional moisture from adjacent areas providing the highest production potential in the study area. The soils are deep, well drained, and moderately coarse textured. The soil has good permeability with a high intake rate and a moderately high water-holding capacity. Due to previous management, the site has deteriorated to a brush-dominated community producing one-third to one-half of its potential.

This valley grassland community now supports sparse vegetation including such species as western wheatgrass, letterman needle grass, green rabbitbrush, big sage, and black sagebrush. Grasses make up nearly 21 percent of the composition with shrubs and forbs at 70 percent and 9 percent, respectively. Annual production was equivalent to 873 pounds per acre. Vegetation provides 34 percent cover.

The climax state of this site produces from 1,000 to 3,000 pounds per acre annually which is a primary factor separating this subdivision

from other sites. Grasses should be the dominant cover for this site, including such species as western wheatgrass, streambank wheatgrass, wildrye, squirreltail, bluegrasses, and needle-and-thread representing 70 percent of the composition. Big sage will also be present.

Sandy foothills

The sandy foothills area, lying to the west of the stony foothills site, occurs as gently rolling hills. Soils are sandy loams to loamy sand. Water-holding capacity is low due to the sand content, but it does take water rapidly making it favorable for certain flora. Permeability is moderate, with surface runoff slow. Erosion hazard is moderate to high under deteriorated conditions.

Present vegetation is characteristic of a sagebrush-grassland-type community. Big sagebrush is the dominant vegetation, having a composition of 21 percent. Streambank wheatgrass is the most frequently occurring grass, totaling 12 percent composition, followed by other grasses such as bluegrass, junegrass, bluebunch wheatgrass, and western wheatgrass listed in respective order. Total annual production was considered below potential for this site at 559 pounds per acre. Vegetation provides 46 percent cover to the site.



Vegetation typical of the sandy foothills range site.

The potential for this site is moderately high for the area in which it is located. During favorable years, production may be as high as 1,200 pounds per acre with a minimum production of 600 pounds per acre. Grasses such as western wheatgrass, streambank wheatgrass, basin wildrye,

Indian ricegrass, bluegrass, and needle-and-thread are most likely to inhabit this type of community under climax conditions. Shrubs should only account for 15 percent of the composition.

Rolling loam

The rolling loam site was one of the three subdivisions which were delineated based on conditions. The rolling loam site, which was rated in good condition, accounts for a large portion of the study site and is located directly north of the stony foothill site in the western portion of the unit. The area rated in poor condition is located in the eastern portion and lies above clayey slopes. The soils are a deep, well drained series having slow permeability and high water-holding capacity.



Vegetation typical of the rolling loam range site.

The vegetation on each classified site varies greatly due to past management practices. The portion, which was rated in good condition, has a high percentage of grasses and forbs accounting for 80 percent of the vegetation. On the other hand, the site in poor condition has approximately 72 percent shrubs which have had a direct competitive impact on more desirable species. Streambank wheatgrass and western wheatgrass are the most common grasses encountered on these sites. Big sagebrush was the most common shrub, with certain locoweeds inhabiting the more favorable locations within the area. Present production for good- and poor-conditioned sites totaled 671 pounds per acre and 993 pounds per acre, respectively. The increased annual production for the poorer site is due to the biomass of shrubs in relation to that of

grasses. Vegetative cover totaled 48 percent on the good condition site and 29 percent on the poor condition site.

Climax vegetation is that of an open stand of sagebrush with an abundance of grasses, 75 percent composition, such as bluebunch wheatgrass, junegrass, squirreltail, and needle-and-thread. Potential production ranges from 500 to 1,000 pounds per acre annually.

08B unnamed

This area runs parallel to Lay Creek drainage within the study site. Soils are deep, well drained, and are located on level to gently sloping stream terraces and valley bottoms. Permeability and available water capacity is moderate with surface runoff slow. Range site classification is unknown along with potential composition and production.

The present vegetation supporting this area is stable with 12 percent bluebunch wheatgrass, 7.5 percent western wheatgrass, 10.5 percent streambank wheatgrass, and an overwhelming 36 percent Indian ricegrass to total well over half the composition. Shrubs account for only 20 percent of the composition with undesirable forbs making up the remaining composition. Annual production was 569 pounds per acre with vegetative cover totaling 56 percent providing the highest cover in the study area.

Stony foothills

This area includes strongly sloping to very steep topography. Soils are medium textured, rocky, with deep to shallow subsoils. The soils are well drained, moderately permeable, but generally have a low available water-holding capacity. Associated with the steep slopes is a high water erosion hazard in the absence of vegetative cover. This range site was divided into different categories based on its present condition. In one instance juniper is present comprising 91 percent of the total composition, while the other subdivision supports 62 percent juniper. This 91 percent tree composition affects grass and forb production, resulting in a poorly conditioned range site. Composition within this site is 3 percent grasses, 2 percent forbs, 4 percent shrubs, while the rest is classified as tree composition. The site in fair condition is composed of 15 percent grasses, 5 percent forbs, and 18 percent shrubs. The poor site produced 1,315 pounds per acre taking into account the large percentage of juniper. Cover for grasses, forbs, shrubs, and trees on this area is 11 percent, 5 percent, 6 percent, and 14 percent, respectively. The subdivision, rated in fair condition, produced 518 pounds per acre with 23 percent grass cover and 10 percent tree cover.

The potential for the stony foothill site is 400 to 800 pounds per acre. Grasses should be the dominant vegetation under climax conditions, making up 60 percent of the composition. Shrubs would include such species as mormon tea, bitterbrush, and certain sagebrushes to total 30 percent of the composition.

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Vegetation typical of stony foothills range site.

Site Hydrology and Water Supply

Ground water

Ground water in the Lay Creek Federal Coal Management site occurs under confined and unconfined conditions in permeable sandstones of the Fort Union Formation of Tertiary Age and under unconfined conditions in alluvial sand-and-gravel aquifers of Quaternary Age. The individual sandstones of the Fort Union are fine grained and poorly sorted. Transmissivity ranges from 22 to 76 square feet per day in the sandstones and has been estimated to be about 3,000 square feet per day in the alluvium. Hydraulic conductivity averages about 1 foot per day for the sandstone aquifers. Specific capacities for wells penetrating the sandstone aquifers are less than 1 gallon per minute per foot for drawdown. Yields from wells, less than 500 feet deep and penetrating at least 150 feet of saturated sandstone, would be about 10 gallons per minute.

A drill hole core from the Fort Union was obtained from the Bureau of Reclamation and analyzed for horizontal and vertical permeability by Core Laboratory, Inc. The results of these tests are shown in Table 10. Smaller permeabilities are indicative of siltstones with interbedded shales where the clay content in the siltstones is the primary control of the permeability. The results of the core analysis support the

Table 10
Core-analysis results^{1/}
U.S. Bureau of Reclamation Drill Hole 4

Depth (feet)	Permeability (millidarcys)		<u>Horizontal permeability</u> <u>Vertical permeability</u>	Horizontal hydraulic conductivity (feet per day)	Vertical hydraulic conductivity (feet per day)
	Horizontal	Vertical			
42.0	21	17	1.24	0.051	0.041
64.9	0.04	0.07	.57	1.0×10^{-4}	1.7×10^{-4}
142.0	479	428	1.12	1.67	1.04
177.0	595	541	1.10	1.45	1.32
228.0	251	279	.89	.61	.68

^{1/} Analysis by Core Laboratory, Inc.

aquifer test data. Hydrologic data for all wells in and adjacent to the tract are summarized in Table 11. Figure 14 on page 59 shows the location of all Geological Survey observation wells in the study area.

The configuration of the potentiometric surface in the Fort Union Formation is similar to the configuration of the topography so that all sandstones in the formation are probably saturated below the level of the valley floors. At higher altitudes along the ridgetops, the sandstones tend to be drained to a depth of several hundred feet.

The Fort Union Formation supplies water to four wells used for livestock watering. The alluvial aquifer supplies water to one irrigation well in Bord Gulch and to one domestic well in Lay Creek Valley. Elsewhere on the tract, the alluvial aquifer is not being used.

On the basis of chemical analyses, water in the sandstones of the Fort Union Formation contains about 900 to 1,400 mg/L of dissolved solids and is a sodium bicarbonate or sodium sulfate type with lesser amounts of calcium and magnesium. Chemical analyses of samples obtained from three Geological Survey observation wells are shown in Table 12. Water from wells SB00809329ACC and SB00809330DCA was a sodium bicarbonate type, and water from well SB00809425DCC was a sodium sulfate type. The relatively large sulfate concentration in water from well SB00809425DDC probably was derived from iron sulfides contained in the interbedded shales. A possible mechanism is that the sulfur is first oxidized to sulfate and then as the water migrates down-gradient, the sulfur is reduced back to iron sulfides in the presence of sulfur-reducing bacteria. The iron sulfides precipitate, but the calcium carbonates disassociate and bicarbonate is formed. Increased sodium is derived by cation exchange. The sodium bicarbonate water is, therefore, a result of dilution and of the activity of sulfur-reducing bacteria.

Only those trace elements that are known to occur in coal formations in the Rocky Mountain area are listed in Table 12. All of the trace element concentrations were less than standards established by the Environmental Protection Agency (1976, 1977)^{1/} for drinking water except for iron concentrations in water from wells SB00809329ACC and SB00809425DCC and the manganese concentration in water from well SB00809425DCC. Because of the associated heavy metals, these concentrations were not unusual. The abnormal phosphorus concentration in water from well SB00809330DCA may have been the result of residual drilling fluids.

Water in the alluvium contains about 200 to 700 mg/L of dissolved solids and is a calcium bicarbonate type.

^{1/} Environmental Protection Agency. 1976. National Interim Primary Drinking Water Regulations: Report 570/9-76-003, 159 p.

_____. 1977. National Secondary Drinking Water Regulations: Federal Register, v. 42, No. 62, Thursday, March 31, 1977, Part I, p. 17143-17147.

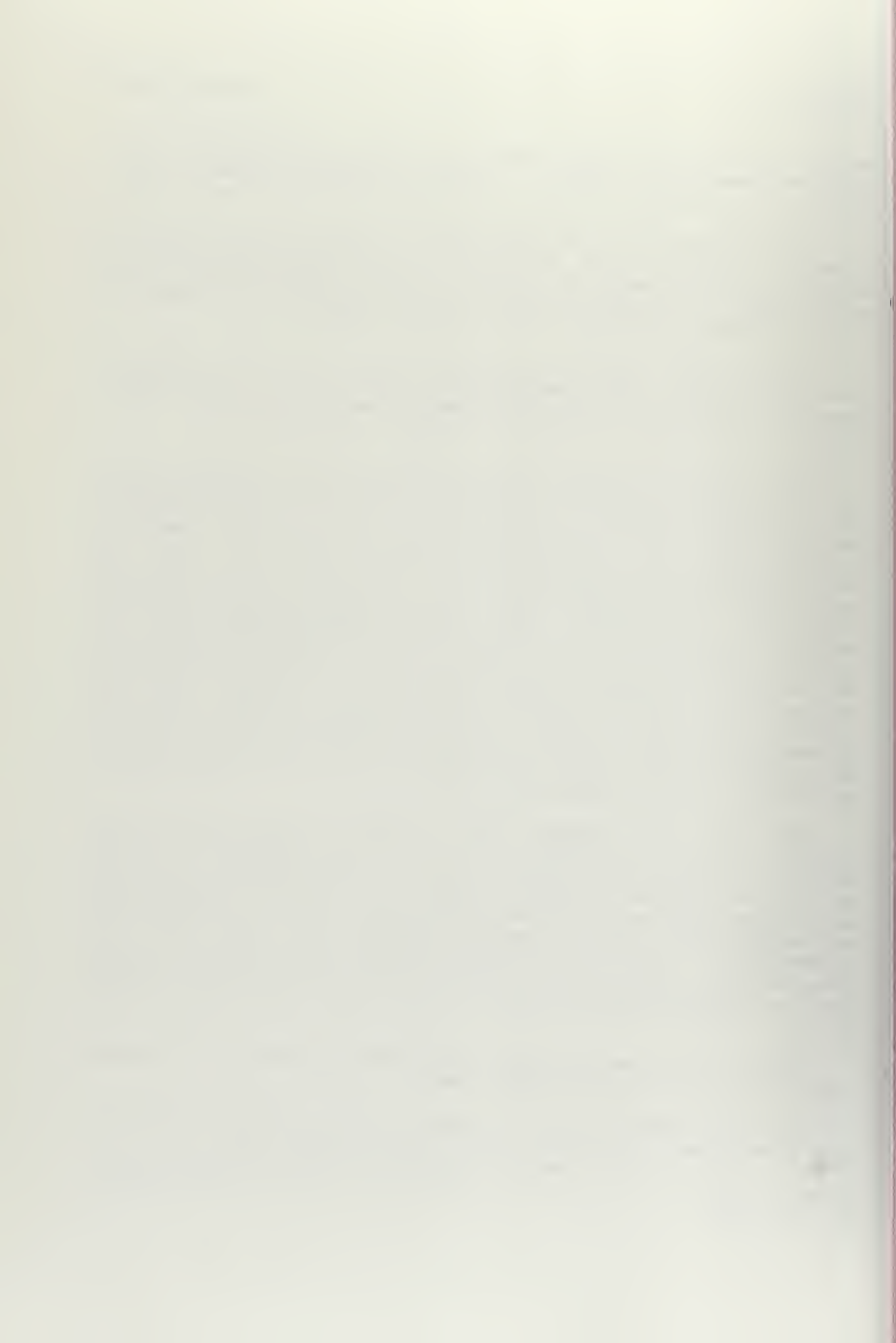
Table 11
Hydrologic data for wells in and near the Lay Creek study site

Well No.	Depth (feet)	Depth of static water level (feet)	Aquifer ^{1/}	Transmissivity (feet squared per day)	Hydraulic conductivity (feet per day)	Specific conductance (micromhos per centimeter at 25° C)	Dissolved-solids ^{2/} concentration (milligrams per liter)	pH	Use of water
1	187	120.9	Tfu						Livestock
2			Tfu			1,800	1,300		Livestock
3	153+	153+	Tfu						Livestock (not used)
4	44	14.39	Qal			250	180	7.25	Unused (no pump)
5	165								Dry hole
6	500+	3.80	Tfu	2.6	0.05	1,450	900	7.4	USGS observation well
7	80		Qal	3,000+		1,000	700	7.05	Irrigation
8	430	97.69	Tfu	47	.26	1,815	1,218	8.2	USGS observation well
9	400	76.10	Tfu	31	.81	1,650	1,200	8.4	USGS observation well
10	30		Qal			450	320		Domestic
11		Flows ^{3/}	Tfu			2,050	1,400	8.7	Livestock
12	600	52.24	Tfu	22	.13	2,012	1,346	7.4	USGS observation well

^{1/} Aquifer: Tfu = Fort Union Formation; Qal = alluvium.

^{2/} Obtained by multiplying specific conductance by 0.7, except for wells 6, 8, and 12.

^{3/} Less than 0.5 gallon per minute.





UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LAY CREEK COAL STUDY
HYDROLOGY

FIGURE 14

Table 12
Water quality data for selected wells completed in the
Fort Union Formation

	Well		
	SB00809329ACC	SB00809425DCC	SB00809330DCA
Constituents (milligrams per liter, except as noted)			
pH (units)	7.4	7.4	8.2
Specific conductance (micromhos per centi- meter at 25° C)	1,450	2,012	1,815
Water temperature (de- grees Celsius)	11.5	11	11
Calcium, dissolved	11	37	4.2
Magnesium, dissolved	6.2	12	1.2
Potassium, dissolved	4.6	5.8	3.2
Sodium, dissolved	<u>1</u> /330	<u>1</u> /400	<u>1</u> /470
Chloride, dissolved	38	12	10
Fluoride, dissolved	2.6	0.4	4.4
Sulfate, dissolved	<u>1</u> /170	<u>1</u> /660	<u>1</u> /310
Bicarbonate, as CaCO ₃	<u>1</u> /338	219	<u>1</u> /409
Total hardness, as CaCO ₃	53	140	17
Dissolved solids	900	1,346	1,218
Trace elements (micrograms per liter)			
Aluminum, dissolved	420	640	50
Arsenic, dissolved	2	0	1
Boron, dissolved	270	160	200
Bromide, dissolved	100	100	100
Cadmium, dissolved	1	1	1
Iron, dissolved	730	680	90
Lead, dissolved	5	0	2
Manganese, dissolved	30	60	4
Molybdenum, dissolved	35	0	22
Phosphorus, dissolved	10	0	110
<u>1</u> / Major ion.			

Surface water

All stream channels draining the study site are ephemeral. Lay Creek, which flows southwestward across the central part of the site, may have standing pools of water along its course throughout the summer. Lay Creek and its principal tributary, Bord Gulch, have channel gradients of about 40 feet per mile. Channel gradients of other streams draining the site range from about 250 to about 400 feet per mile.

Annual runoff from the study site probably does not exceed about 200 acre-feet. Estimated discharges of Lay Creek are 700 ft³/s (cubic feet per second) for a 10-year flood, 1,350 ft³/s for a 50-year flood, and 1,700 ft³/s for a 100-year flood. Maximum discharge of other streams draining the site should not exceed 200 ft³/s for a 100-year flood.

Surface runoff from the tract probably contains about 500 to 1,000 mg/L of dissolved solids; it probably is a calcium-magnesium-sulfate-type water. This water is suitable for livestock and wildlife.

The lower reach of Bord Gulch and the reach of Lay Creek for at least a mile upstream and downstream from the mouth of Bord Gulch probably can be classified as alluvial valley floors as defined in Public Law 95-87. Both subirrigation and flood water irrigation are occurring in these reaches. Water in the alluvium at the upstream ends of these reaches contains less than 500 mg/L of dissolved solids. Water in pools in the channel of Lay Creek at the downstream end of the subirrigated area contains about 2,100 mg/L of dissolved solids. This may be due to concentration by evaporation.

Erosion and Sedimentation

Erosion is most pronounced on south-facing slopes where steep gradients, a sparse plant cover, and gullied channels indicate sediment yields in excess of 2 acre-feet per square mile per year. The north-facing dipslope surface that occurs throughout most of the site is comparatively stable; but some actively eroding channels, as much as 10 feet deep, indicate local erosion. Sediment yields from this part of the site probably average 0.3 to 0.5 acre-foot per square mile per year. The average sediment yield from the entire site is estimated to be about 0.8 acre-foot per square mile per year.

Most of the sediment eroded from the site is deposited in small reservoirs or stock ponds along the valleys of Bord Gulch and Lay Creek. As a result of sedimentation, most reservoirs have little or no remaining capacity to store water.

Wildlife

The study area provides habitat for a variety of wildlife species inhabiting the sagebrush-grassland ecosystem. The following is a list of the more common species that may be found on the study area.

antelope	kestrel
mule deer	sharp-shinned hawk
elk	sage grouse
bobcat	killdeer
coyote	common snipe
red fox	longbilled curlew
white-tailed prairie dog	American avocet
cottontails	mourning dove
jackrabbits	great-horned owl
skunk	nighthawk
weasel	broadtailed hummingbird
muskrat	Say's Phoebe
mink	horned lark
badger	violet-green swallow
Merriam's shrew	bank swallow
Townsend's big-eared bat	barn swallow
big brown bat	cliff swallow
long-eared myotis	crow
little brown myotis	magpie
small-footed myotis	brown thrasher
yellow-bellied marmot	sage thrasher
ground squirrel	robin
deer mouse	meadowlark
grasshopper mouse	mountain bluebird
sagebrush vole	cedar waxwing
long-tailed vole	loggerheaded shrike
porcupine	red-winged blackbird
waterfowl	Towhees
turkey vulture	sparrows
red-tailed hawk	tiger salamander
Swainson's hawk	boreal toad
rough-legged hawk	horned toad
ferruginous hawk	leopard frog
golden eagle	western garter snake
bald eagle	bull snake
marsh hawk	prairie rattlesnake
prairie falcon	lizzards
thirteen-lined ground squirrel	killifish

About 20 to 40 antelope may be found the year round in the study area. These are a segment of the Big Gulch-Lay Creek drainage herd which consists of 200 to 400 animals. The area is within the boundaries of Antelope Management Unit A3W.

Mule deer utilize the area as a migration route and winter area.

Elk have been observed on the east end of the study area. They do not commonly utilize the area.

The data for songbirds, small mammals, and reptiles are lacking. Those species noted in the Maybell and Great Divide URA associated with sagebrush-grassland, riparian, and cliff areas may be expected to be found on the study site although biological factors such as numbers, distribution, habitat requirements, and season of use are unknown at the present.

The raptors listed, with the exception of the bald eagle, are common users of the area. The bald eagle can be listed as an occasional winter user.

An active golden eagle nest complex of four nests is found in sec. 6, T. 7 N., R. 93 W. Cliffs in secs. 5 and 6 have potential nest sites for other falcons and hawks as well as eagles. These are located within 1/2 mile of the area to be mined and within 1/8 to 1/5 mile of County Road 17. Two additional active golden eagle nests are located 1/3 mile south of the study area in sec. 31, T. 8 N., R. 92 W., and sec. 36, T. 8 N., R. 93 W. Nesting activity for other raptors has not been documented within the study area.

No threatened or endangered species are known to inhabit the study area, although bald eagles are occasional winter visitors. The presence of black-footed ferrets cannot be discounted as prairie dogs are found within the study area.

There are no wild horses using the study area.

Sage grouse are known to inhabit the study area. One known strutting ground is located in the NE 1/4, sec. 25, T. 8 N., R. 94 W. A suspected strutting ground is located in sec. 26, T. 8 N., R. 93 W.

Aquatic and riparian habitats are found along Lay Creek. These areas provide nesting, roosting, and feeding habitat for waterfowl, shorebirds, songbirds, and raptors. The presence of limited perennial water and large trees makes this a high value habitat area.

Cultural Resources

A judgmental reconnaissance survey for prehistoric and historic values was conducted on a potential coal lease tract on Lay Creek by BLM archaeologists during July 1979. Within this tract lies the Lay Creek reclamation study area.

Three historic sites and six prehistoric isolated finds were identified on the site. The historic sites include two homesteads and one trash dump, all located in drainage bottoms. The prehistoric isolated finds include one projectile point midsection (base and tip missing), one find of two flakes, a flake along with leaf fossils, and three findings

of one flake each. All the prehistoric isolated finds, except one, are located on the ridgetops and benches. The one exception is located on the first terrace above Lay Creek.

No evaluation for determination of eligibility and inclusion to the National Register of Historic Places has been done, pending completion of a Class III survey. Based on data gathered during the reconnaissance survey, the probability is 80 percent for additional prehistoric sites/isolated finds being found on the ridgetops and benches, particularly in the juniper areas, and 30 percent for the remaining area. A 70 to 80 percent probability exists of finding additional historic sites in drainages, especially where access is available and 10 percent for the existing area (ridgetops, slopes, and rolling hills) within the study tract.

Visual Resources

The visual resources of the Lay Creek area are typical and not uniquely different from the adjacent drainage areas west of Craig. Topography of Lay Creek, besides the drainage basin, is best described as rolling hills with a few abrupt sandstone outcroppings. Two Visual Resource Management (VRM) Classes exist within the study site; a Class III for the Lay Creek drainage and a Class IV for the remaining portion of the site. The area confined within the Lay Creek bottom area is affected by agricultural production of livestock feeds. The remaining portion of the tract, besides a few dry upland farming fields is comprised of native vegetation, predominantly sagebrush, grasses, and weedy forbs. Juniper trees are present on outcroppings and steep stony slopes.

The VRM definition of Class III is that contrasts of basic elements (form, line, color, and texture) caused by a management activity may be evident and begin to attract attention but should remain subordinate to the existing landscape. Strip mining, vegetation removal, mining facilities, roads, and rail spurs will be an overwhelming contrast from the natural terrain and highly visible from Moffat County Road N-17.

The definition of VRM Class IV is that contrast may attract attention and be a dominant feature of the landscape in terms of scale but should repeat the form, line, color, and texture of the characteristic landscape. Severe disruption to the landscape, caused by topsoil and overburden removal, roads, stockpiles, and heavy equipment associated with surface strip mines would be apparent on a short-term basis until the area is effectively reclaimed. Severe visual impacts would be manifested on any areas adjacent to the visual corridors of MCR-N-17.

CHAPTER III

OBJECTIVES OF RECLAMATION

Legal Requirements

The development of Federal coal resources will require the lessee to comply with all Federal regulations. Further, since the lessee or permittee will not be an instrumentality or agent of the Federal Government, he must also comply with State and local regulations.

Federal

The first major Federal mine-land reclamation regulations were published in the Federal Register, Volume 41, No. 96, May 17, 1976, and were the forerunners to the Surface Mining Control and Reclamation Act of August 1977. This Act, Public Law 95-87, clearly defines the regulations and requirements for control and regulation of surface mine development of coal resources. Section 515 of this Act, Environmental Protection Performance Standards-Permit Requirements, says in part--"(a) Any permit issued under any approved State or Federal program pursuant to this chapter to conduct surface coal mining operations shall require that such surface mining operations will meet all applicable performance standards of this chapter, and such other requirements as the regulatory authority shall promulgate." General Standards--"(b) General performance standards shall be applicable to all surface coal mining and reclamation operations."

The following standards, generalized and summarized, but not inclusive, shall be required as a minimum.

1. Conduct surface coal mining operations to maximize utilization and conservation of solid fuel resources.
2. Restore the land to a condition capable of supporting the uses which it was capable of prior to any mining, or a higher or better use.
3. Backfill, compact, and grade in order to restore the approximate original contour.
4. Stabilize and protect all surface areas to effectively control erosion and attendant air and water pollution.
5. Remove the topsoil in a separate layer; replace it on backfill area.
6. Restore the topsoil or the best available subsoil which is best able to support vegetation.

7. Identify all prime farmland.
8. Create, if authorized, permanent impoundments of water.
9. Conduct any augering operation in a manner to maximize recoverability of mineral reserves and seal all auger holes.
10. Minimize the disturbances to prevailing hydrologic balance.
11. Stabilize all waste piles and assure the final contour.
12. Refrain from surface coal mining within 500 feet from active or abandoned underground mines to prevent breakthroughs.
13. Meet such other criteria as are necessary to achieve reclamation in accordance with the purposes of this chapter.

Variance provisions, specifications, and mitigating circumstances are described in addition to the above performance standards.

Other Federal regulations that apply to surface mining and development of coal resources include (1) the National Environmental Policy Act of 1969 (Public Law 91-190), (2) the Endangered Species Act of 1973 (Public Law 93-205), (3) the Federal Land Policy and Management Act (Public Law 94-529), and the BLM Organic Act.

State

Surface mining in Colorado is regulated by the "Colorado Open Mining Land Reclamation Act, Colorado Revised Statutes." Chapter 92, Article 13, as amended September 15, 1973, specifically covers reclamation of surface-mined lands. It requires in part--"A permit, bond, and filing fee are required from all surface-mined operations." The bond is set at an amount to ensure the completion of the reclamation plan.

The authority for enforcement of this law rests with the Executive Division of the Department of Natural Resources. Other applicable laws or regulations include the Colorado Water Pollution Control Act, Chapter 66, Article 28, Colorado Revised Statutes as amended.

Local

There are county zoning regulations that affect strip-mining operations; namely, in the area of sanitation practices, disposal of wastes, and the use of culinary water.

The local regulations are not intended to be as explicit regarding development and reclamation of surface-mined lands as are the Federal and State regulations. The successful reclamation and revegetation of

surface-mined areas will, however, depend upon an environmental awareness and an intensive and coordinated effort by industry, the public, and State and Federal regulatory agencies.

Secretary of the Interior Unsuitability Criteria
Supplement to BLM Management Framework Plan

Section 522 of the Surface Mining Control and Reclamation Act requires the Secretary of the Interior to conduct a Federal lands review in order to determine those lands unsuitable for surface coal mining. Through the application of specific "unsuitability" criteria, areas within the Williams Fork Planning Unit have been designated not suitable for coal leasing. These unsuitable areas contain key features and environmental sensitivities which make mining environmentally unacceptable or not compatible with other land uses.

Two areas within the Lay Creek study site have been designated not suitable for coal leasing as shown in Figure 15. One area, in sec. 30, represents a buffer zone protecting an active strutting ground for sage grouse from disturbance. The other area, in secs. 26 and 27, represents surface ownership against leasing of Federal coal under their land.

Detailed information on the Federal Lands Review process, unsuitability criteria, and supportive data are available in the Management Framework Plan Supplement for the Williams Fork Planning Unit at the Craig District Office of the Bureau of Land Management, 455 Emerson Street, Craig, Colo. 81625.



FIGURE 15

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LAY CREEK COAL STUDY

Areas considered unsuitable for mining after applying the Unsuitability Criteria.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS FOR RECLAMATION

Physical and Chemical Characteristics of Available Plant Growth Media

Soils

The naturally occurring soils within the study area generally have few major problems relative to their potential use as a plant growth media. Physical properties as shown by the many soil profiles are good, with most surface layers or topsoil textures in the sandy loam to clay loam range. Soil profiles which are shallow, less than 8 inches in depth, were designated as unsuitable for use as a plant growth media.

Chemical properties of all surface soils were adequate; and where sufficient soil depth occurred, most soils were designated as suitable for stockpiling and reuse as a plant growing media.

Most subsoils were suitable at least to the 3-foot depth for most of the lands classified as classes 1 and 2. In a few instances the subsoil was classified as having limited suitability due to moderately high electrical conductivity readings and moderately high SAR values. Most of the subsoils classified as unsuitable for plant growth media were downgraded because of either high electrical conductivity (high soluble salts), SAR values, or exchangeable sodium percentages. The unsuitable subsoils were generally of fine textures (clay and silty clay) with low estimated hydraulic conductivity rates.

Most lands with unsuitable topsoils and subsoils were those areas of shallow residual soils developed from underlying shales. They are found principally in the northern part of sec. 30 in the vicinity of drill hole No. 4. They also include the shallow soils of the broken, rough, eroded badlands. They are designated as class 6 lands on the soil maps.

Overburden materials

The overburden and interburden material above and between coal seams consists of sandstone, shale, and siltstone. Sandstone comprises approximately 68 percent of the overburden; shale, 19 percent; sandstone/shale, 8 percent; and coal, 5 percent in drill holes 1, 2, and 3. Geologic material in drill hole 4 consists of less sandstone, approximately 46 percent; while shale, siltstone, and shale/siltstone make up 49 percent and coal 5 percent. Coal thickness in all four holes is nearly uniform and ranges from 10 feet thick in drill hole No. 2 to 14.5 feet thick in drill hole No. 4.

Most of the overburden material is unsuitable or of limited suitability as a plant growth media. The suitability as determined from core sample analyses is summarized in Table 13 on the following page.

The geologic overburden materials in drill holes 1 and 2 seem to possess better characteristics, both physical and chemical, for use as a plant growth media. Drill holes 3 and 4 are almost all unsuitable or of limited suitability. Because of the limited or unsuitable characteristics of most of the overburden materials, it will be necessary during reclamation and revegetation to require a topsoil dressing be placed over the raw overburden spoil banks.

Quantities of Plant Growth Media and Overburden

The land classification study as discussed previously identified 1,967 acres of land delineated as suitable for use as a plant growth medium. These areas are shown on Figure 16. The classification identified approximately 1,133 acres of class 1 with a minimum strippable depth of 42 inches. Class 2 lands total 494 acres and have a minimum strippable depth of 18 inches. Class 3 lands, while suitable as a plant growth media, are shallow; less than 8 inches; or have other deficiencies that limit their use as a strippable plant growth media. These deficiencies are ultimately expressed as an economic factor or limitation as to the ease of stripping and stockpiling for use as a top dressing on overburden spoil banks.

It is estimated that approximately 1,967 acres of suitable plant growth medium overlies strippable coal. Utilizing soil depth and area it is felt that sufficient soil or plant growth media are available for use as replaced topsoil for reclamation of the study site.

The bulk of the overburden and interburden material at the Lay Creek site is of limited or unsuitable quality for use as a weathered plant growth medium. Most of the overburden material overlying strippable coal is composed of the sandstone and shale members of the Fort Union Formation. Cast overburden from this formation tends to weather rather rapidly into spoil banks of silt- and clay-sized particles. Because of the physical and chemical properties of this material it will be necessary to top dress the spoil banks to a minimum depth of 4 to 6 inches of replaced topsoil to facilitate reclamation and revegetation.

General Feasibility for Revegetation

The feasibility for revegetation and reclamation of the Lay Creek site will depend, as discussed, on a number of factors including climate; soil; and geologic, hydrologic, topographic, and biotic materials. These factors along with the postmining land use selection will in large part determine the feasibility and success of revegetation and reclamation. The information gathered during the study indicates an opportunity exists

Table 13
Overburden suitability

Drill Hole No.	Thickness or depth (feet)	Material	Limiting deficiency				Weathering rate (percent)	Suitability rating
			pH	ECx10 ³	ESP	SAR		
1	42.0- 50.6	Shale	8.2	1.02	2.9	0.5	38	Limited
	52.5- 58.0	Shale	7.8	2.08	1.4	.4		Limited
2	27.1- 48.0	Shale	8.3	1.67	2.1	1.0	100	Limited
	58.0- 75.0	Shale	8.3	.99	3.5	.5		Limited
	129.5-146.9	Sandstone	8.6	1.02	6.7	.5		Limited
	177.3-204.5	Shale	8.4	1.45	1.9	1.8		Limited
	217.5-252.1	Sandstone	9.5	1.00	7.5	7.0		Limited
	271.4-303.4	Sandstone	8.4	1.62	11.0	2.5		Limited
3	13.6- 25.1	Shale	9.4	1.44	12.0	14.0	100	Unsuitable
	28.6- 38.7	Shale	9.8	1.46	22.0	15.0		Unsuitable
	47.4- 55.0	Sandstone	9.9	1.12	37.0	15.0		Unsuitable
	55.0- 65.2	Shale	9.9	1.44	35.0	19.0		Unsuitable
	71.7- 86.9	Sandstone	9.9	1.86	39.0	24.0		Unsuitable
	102.6-123.9	SS/shale	9.9	1.43	36.0	15.0		Unsuitable
	184.2-200.1	Sandstone	9.5	1.49	30.0	21.0		Unsuitable
	200.1-210.9	Sandstone	9.1	1.76	26.0	17.0		Unsuitable
	Coal - 11.3							
	225.4-254.1	Siltstone	9.5	2.10	44.0	35.0	61	Unsuitable
4	13.0- 22.6	Siltstone	9.4	1.04	6.1	11.0	100	Limited
	22.6- 36.5	Shale	9.9	1.02	27.0	14.0		Unsuitable
	36.5- 47.2	Sandstone	9.8	1.71	36.0	25.0		Unsuitable
	57.0- 66.3	Sandstone	9.9	2.21	39.0	27.0		Unsuitable
	69.5- 74.0	Siltstone	9.9	1.44	37.0	22.0		Unsuitable
	74.0- 82.1	Shale	10.0	1.39	42.0	21.0		Unsuitable
	95.5-111.3	Siltstone	9.7	1.50	36.0	25.0		Unsuitable
	120.4-192.0	Sandstone	9.9	1.53	39.0	21.0	0	Unsuitable
	192.0-223.2	Shale	9.8	1.70	38.0	23.0		Unsuitable
	Coal - 14.5							

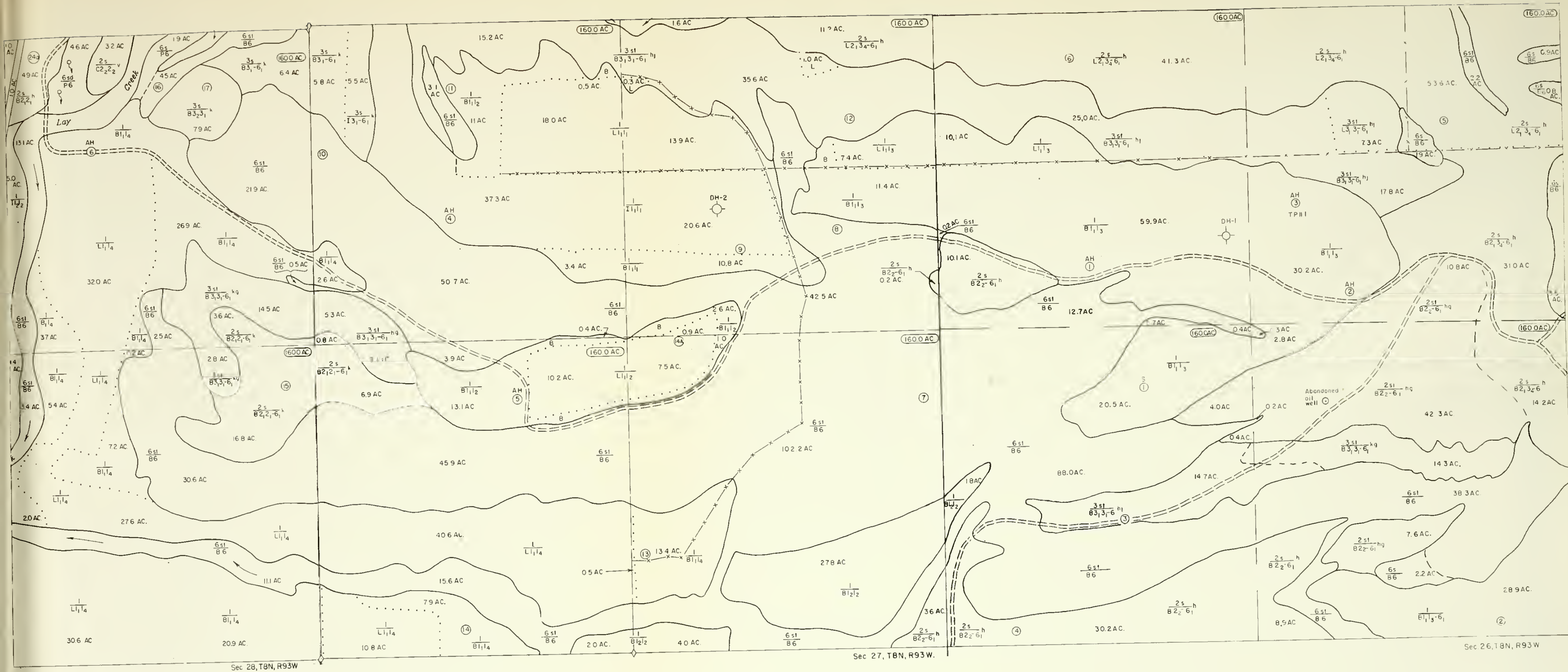


FIGURE 16
 UNITED STATES
 DEPARTMENT OF THE INTERIOR
 BUREAU OF RECLAMATION
 LAY CREEK SITE
 COMPOSITE LAND CLASS MAP
 SHEET 2 OF 2

to successfully revegetate and reclaim the surface-mined areas of Lay Creek when utilizing proper techniques and management practices.

The study also reveals possible problems associated with using the overburden material as plant growth media. The most significant problem would be the high sodicity of much of the overburden material, including some of the deep subsoils, and a related problem of slow permeability. These conditions preclude the use of the overburden as a plant growing media, except as it is top dressed with replaced topsoil.

The study indicates a feasibility exists for successful revegetation and reclamation of surface-mined areas using the latest techniques and management practices. It must be noted, however, that for restoration to the original ecosystem, a longer time frame would be required.

Nutrient deficiencies

Greenhouse studies on selected soil and overburden samples from the Lay Creek site indicate phosphorus and/or potassium deficiencies exist or are common to nearly all samples. A potential micronutrient deficiency especially for copper exists. It was pointed out, however, that micronutrient deficiencies would not be considered a major fertility problem. The phosphorus and potassium deficiencies can be corrected by applying fertilizer during the revegetation and reclamation process.

Climate and water

Variability of precipitation is the greatest constraint to revegetation. The following management practices should be used to improve revegetation of mined lands.

1. Reclamation strategy should include plans and resources for multiple seeding attempts since the establishment of vegetation is likely to fail occasionally. Supplemental water should be considered, although it probably would be more economically reasonable to have an occasional failure and replanting.
2. Mulching, special shaping, and contouring of the land surface should be considered for increasing soil moisture capacity and storage capability and reducing evapotranspiration demand.
3. Snow management techniques should be used to reduce the chances of winterkill of young plants, increase soil moisture into spring and summer, and decrease wind erosion and desiccation by occasional high winds.

Careful selection of plant species with respect to climate sensitivity will be critical. The following factors should be considered in selection of desirable plant species to be used in revegetating the site.

1. Large daily variations in temperature and precipitation will demand that hardy species be chosen that can withstand harsh changes during critical developmental stages.
2. Fall seeding (for spring germination) is preferred to take full advantage of spring precipitation for plant establishment. Dates for fall seeding should be based on seed germination and ambient temperature requirements. Late fall warm periods may occur and cause premature germination resulting in a revegetation failure.

Toxic materials

Selected tests from the Greenhouse Study (Appendix E) on samples from the study site indicate no significant accumulations or deleterious effect from toxic materials other than sodium. Data from samples tested did indicate a possible copper deficiency in some overburden materials. Tests for arsenic, selenium, and lead fell below the 10 ppm detection limit.

Recommendations for Reclamation to Suit Selected Postmining Use

Handling and placement of soil and overburden material

The land areas delineated as suitable (land classes 1 and 2) for stockpiling, and ultimately as replaced topsoil, should be mechanically stripped and stockpiled in such a way as to minimize compaction and reduce wind and water erosion. During the stripping and stockpiling operation, care should be exercised so as to reduce contamination from unsuitable layers of both soil and overburden materials.

The overburden (bedrock) material should be removed and cast whenever possible so that the more unsuitable layers are buried deep, with the suitable and limited suitable materials at or near the surface.

Since surface mining by its nature destroys completely the original surface or topsoil, it is necessary to develop a suitable medium for plant growth if reclamation and revegetation is to be accomplished. Topsoil salvage and top dressing is a means of accomplishing this principle and is more acceptable and susceptible to success than the use of overburden materials. The use of overburden materials with satisfactory textural, chemical, and physical properties, coupled with a fertilization program, could provide the mechanical support and be suitable as a plant growth media. This, however, is impractical at the Lay Creek site since a limited amount of suitable overburden material and top dressing will be required.

To accomplish revegetation, surface manipulation of the spoil banks will be a reclamation requirement. This manipulation consists

of modifying the spoil surface into configurations which facilitate postmine land use requirements and blends with the topography and contour of the overall area. To enhance revegetation, surface manipulation must also reduce erosion by reducing the rate and amount of surface runoff, thereby improving plant growth medium moisture conditions which will allow for the establishment of vegetative cover.

Shaping of spoil for aesthetics and erosion control

The cast overburden spoils should be surface manipulated, shaped, and top dressed with replaced topsoil. Revegetation should include vegetative species to conform with the natural ecosystem and the selected postmining land use. Former dryfarmed areas on the mesa lands can be restored by controlling slope and slope orientation through mechanical manipulation of the spoil banks. Restoration of the natural slope and contour would limit slopes to less than 15 percent with a moderately undulating topography.

Restoration of the rangelands and wildlife habitat, including badland areas disturbed by surface mining, will require a greater effort to retain the natural aesthetics of the area. Reshaped spoil banks will need to blend with the existing landscape and still ensure slope stability, control erosion, and establish native vegetation.

Conservation measures needed to ensure erosion control

Control of erosion at the Lay Creek study site will be dependent upon the effective reestablishment of perennial vegetation. The method or methods of mechanical treatment used to establish the vegetative cover on the reshaped spoil will assist in the control of erosion. The main objectives of the mechanical treatment to establish vegetation include (1) treatments to effectively reduce surface runoff and improve water infiltration and (2) methods to increase and store soil moisture.

Methods to accomplish these objectives and enhance the vegetative succession include reshaped and contoured spoil banks, topsoil replacement, contour plowing or terracing, dozer basins, deep chiseling, pitting, ditching, listering or gouging, discing, and mulching. These treatments are not only effective in controlling surface runoff but will also control wind erosion. They assist in conserving moisture by providing catchment basins for snow and runoff and also increase the infiltration rate.

Conservation to control erosion following the reestablishment of perennial vegetation will consist of management practices to control use of the area and establish a healthy plant community. These practices will include a fertilization program, irrigation when necessary, and fencing to control trespass and grazing.

Selection of Species for Seeding

Regulations governing reclamation require a return of surface-mined lands to approximately their natural state and revegetating with predominantly native plants. In a sense, this is an attempt to bypass the stages of secondary succession and produce a stable community.

The native vegetation as it occurred before mining, however, will not be a stable community on postmined land. The entire ecosystem of mined land has been disrupted and changes have occurred from the microclimate to soils developing from different parent material. The scheme of reclamation, as it occurs today, stockpiles soils of several different plant communities. This soil is used to cover an area that supported several plant communities, before mining, with a uniform depth of soil. Then a mixture of predominantly native species is seeded, resulting in a single plant community being established where several occurred before mining. Through secondary succession, nature will establish a vegetative composition of specified plants adapted to the environmental conditions present following reclamation.

Seeding a native mixture to initiate a later stage of secondary succession on strip-mined land is probably the most stable community that can be established with present day knowledge.

The following list of plant species represents the native potential vegetation for the study site. This list should be used in developing a species mixture for revegetation on the study site.

<u>Grasses</u>	<u>Forbs</u>	<u>Shrubs</u>
Thickspike wheatgrass	Vetch	Sagebrush
Slender wheatgrass	Buckwheat	Rabbitbrush
Streambank wheatgrass	Balsamroot	Serviceberry
Western wheatgrass	Phlox	Bitterbrush
Bluebunch wheatgrass	Globemallow	Juniper
Sheep fescue	Lupine	Saltbush
Prairie junegrass	Yarrow	Greasewood
Indian ricegrass	Aster	Shadscale
Sandberg bluegrass	Penstemon	Winterfat
Nevada bluegrass	Herbaceous sage	Fourwing saltbush
Squirreltail	Indian paintbrush	Snowberry
Needle-and-thread	Stoneseed	Horsebrush
Columbia needlegrass	Fleabane	
Letterman needlegrass	Hawksbeard	
Muttongrass	Gilia	
Basin wildrye		
Sand dropseed		
Galleta		

There are no identified endangered or threatened plant species on the study site or surrounding area.

Introduced species which have an adaptation to the area include:

Whitmar wheatgrass	Volga wildrye
Siberian wheatgrass	Durar hard fescue
Crested wheatgrass	Prostrate summercypress
Critana wheatgrass	Vetch
Pubescent wheatgrass	Clover
Russian wildrye	

Reclamation efforts should be directed toward the development of diverse and self-perpetuating plant communities. Because of precipitation patterns of the area, those species which take advantage of early spring moisture, germinate early, and concentrate their growth during the early growing season offer the best choice for stable plant communities. Other considerations which should influence the selection of species for revegetation include (1) their natural adaptation for the area, (2) their ability to establish, (3) their ability to provide cover and soil stability, (4) their nutritional value and palatability for wildlife and domestic livestock, (5) their drought resistance, and (6) their disease resistance.

Seeding Methods

Any practice that would enhance natural revegetation should be initiated in the reclamation process. Plant material cleared from the premining area should be saved and incorporated in the resurfacing soil or used as a mulch. Plant material removal and topsoil removal should follow production of a seed crop. This will allow a seed crop to be stockpiled with the soil and plant material.

Transplanting pads of natural shrubby vegetation will provide a quick wildlife cover and enhance natural revegetation. This can be accomplished with the use of a front-end loader. Mature healthy shrubs can also be transplanted with a tree spade. The front-end loader, however, can transplant more area and provide a greater variety of vegetation.

If a mulch is applied for improvement of soil characteristics, it should be incorporated into the soil before seeding. Adequate nitrogen must be available to break down the mulch. If fertilizers are used to increase soil nutrient levels or to break down soil additives, they should be incorporated into the soil before or during seeding.

Following placement of the plant growth media (topsoil) a seedbed should be prepared. The area to be seeded should be ripped or subsoiled to alleviate compaction by heavy equipment and to enhance water infiltration. The soil preparation should provide an even and firm seedbed to allow regulation of uniform planting depth. Seed should be drilled on the contour or perpendicular to the slope. The depth placement of a seed is roughly proportional to its size. Most grass seed should be

seeded to a depth of 1/2 to 3/4 of an inch. Small seed should be broadcast and seeded to a depth of 1/2 or 3/4 of an inch. This can be accomplished by allowing half the small seed to be planted in the grass seed furrow and the other half to be broadcast behind the grass seed with the minimal amount of cover provided by the drill drags. Large seeds, having long germination periods, should be seeded deeply enough to ensure a moisture supply during germination.

To enhance germination and obtain an established stand of grass, fall seeding is recommended. A rangeland or deep furrow drill should be used.

Bare-root stock or container-grown shrubs should be planted in the early spring. The use of bare-root or container stock should be in conjunction with rodent and wildlife protection. To enhance establishment and growth of shrubs, they should be planted in areas that receive more effective moisture such as north slopes, areas of slow runoff, and areas that are protected from wind and have a low evapotranspiration ratio.

Surface Protection

As discussed in the land suitability section, sufficient topsoil is available for resurfacing the study site; and regulations require a return to the natural state following mining. In this case, lack of root mass and loss of soil structure is perhaps the main difference separating revegetation following mining and revegetation following a burn. The problem will be essentially to hold the topsoil from erosion until sufficient vegetation cover can be developed.

Seasonal wind erosion will perhaps be the greatest effect during reclamation. Although premining wind erosion is not a major factor, mining will void extensive areas of vegetation. Measures to counteract loss of natural wind barriers will be needed to prevent wind erosion during vegetation establishment.

Wind erosion decreases with the reduction of wind velocity hitting the ground. This reduction may be accomplished through surface roughness. A standing stubble or cover crop has proven the most effective surface roughness. A fast growing annual should be used as a cover crop and should either be a sterile hybrid or not allowed to set viable seed. This will allow a quick cover and eliminate competition from the cover crop. Surface roughness can also be produced through tillage operations that form ridges or bring clods to the surface. The tillage operation should be at right angles to the prevailing wind. Applied mulch can also be an effective surface roughness treatment. To be effective, however, the mulch cannot be incorporated into the soil but should be anchored to the soil surface.

Although adequate topsoil is available in the study area to resurface the mined area, adjoining or similar areas may not be as fortunate. It should be noted that existing land disturbance in the area indicates

a very sandy condition will persist if adequate organic matter is not available in the resurfacing material. This condition would occur if overburden material is used as a plant growth media.

Wind erosion control would be very critical should overburden material be used as a resurfacing material, (plant growth media). Sandy material is highly erodible, and its abrasive action and inundating effect can destroy established stands of vegetation. Revegetation studies of sandy material, in an environment similar to the study site, are needed. Generalizations can be made. Only the very minimal sandy area should be exposed at one time. Work should start at the most upwind location to be disturbed and progress downwind. Wind barriers that absorb or deflect the direct impact of erosive winds will be needed. Barriers should be at right angles to the prevailing wind and could consist of almost anything--vegetation strips, picket fence, or rock.

Measures to control water erosion will also be necessary. Surface gouging, contour furrows, and drill furrows should be used for water retention and soil holding in an effort to minimize and control surface runoff and to add water to the soil profile. A cover crop or mulch used for surface stabilization against wind erosion would also be beneficial in controlling surface runoff.

Postmining Land Management

Proper postmanagement of the reclaimed area is essential if reclamation is to be successful. The reseeded area should be protected from grazing until vegetation is sufficiently developed and established to withstand grazing use without damaging the vegetative cover. Once established, a planned grazing system should be used to graze the area.

In the event weed growth prevents the likely survival of the seeded species during establishment, acceptable methods of weed control should be used. If noxious weeds invade the rehabilitation site, acceptable methods of removal should be used. Corrective measures should be taken to stop any erosion.

A portion of the precipitation runoff should be intercepted by reservoirs following reclamation. These impoundments will provide water for wildlife and livestock use.

As indicated in the hydrology section, existing reservoirs have little or no remaining capacity to store water. With the building of new reservoirs, adequate measures should be taken to extend the life of water impoundments as long as possible.

To maintain adequate fertility levels in the soil, a fertility program of several years may be necessary.

CHAPTER V

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APPENDIX A

GEOLOGY



Coal outcrop west of Bord Gulch.

GEOLOGIC DATA
FOR
RECLAMATION EVALUATION
LAY CREEK STUDY SITE
EMRIA STUDY
LAY CREEK, COLORADO

United States Department of the Interior
Bureau of Reclamation
Upper Colorado Region
Division of Design and Construction
Geology Branch

Field Work and Writing
by D. Grundvig
April 1979

GEOLOGIC DATA
FOR
RECLAMATION EVALUATION
LAY CREEK STUDY SITE
EMRIA STUDY
LAY CREEK, COLORADO

INTRODUCTION

The data included within this report was collected as part of the Department of Interior's EMRIA study of the Lay Creek Study Site. EMRIA (Energy Mineral Rehabilitation Inventory and Analysis) is an inter-agency approach to field data collection, analysis, and interpretation of soil, water, overburden, and energy resource data. It is the objective of this program to assure that adequate baseline data is collected and that lease stipulations are established for mined-land reclamation.

As part of this study the Geology Branch drilled four core holes within the study area for the procurement of core samples to be used for the analysis of geological strata in overburden materials. In addition, a geologic map and cross-section was prepared.

LOCATION

The study area is located on the north flank of the Mud Spring Anticline in the southern part of the Wyoming Basin physiographic province of the Rocky Mountain system. The anticlinal axis trends approximately N50°W. The study area is characterized by gentle, north sloping mesas and well incised drainages. Elevations within the site range from 6,400 to 7,000 feet.

REGIONAL GEOLOGY

Exposed rocks in the study site are sedimentary in origin and consist almost entirely of Tertiary age formations. A generalized stratigraphic section of these sedimentary rocks is shown on page 90 (Plate 18, USGS Bulletin 1027). Formation beds within the area strike approximately N85°E and dip gently northward from the axis of the anticline. Older formations of Upper Cretaceous age, underlie the site at depth and are exposed immediately south of the site. The uppermost Cretaceous unit, the Lance Formation, consists of interbedded gray shale, tan to light brown, soft, fine-grained sandstone, and a few coal beds. The formation is about 1,050 to 1,500 feet thick and is succeeded northward by progressively younger rock members.

The Fort Union Formation unconformably overlies the Lance Formation and as encountered by drill holes DH-1 through DH-4, consists of interbedded sandstones, siltstones, shale, and coal. The properties of the sandstone

varied considerably within each hole, ranging from fine- to medium-grained, poorly to well sorted, and weakly to moderately well cemented. Some intervals were very porous and crumbly. Locally, the shale contained leaf and invertebrate fossil remains. Two of the coal seams found in the upper portion of the Formation, the Emerson and Blevin seams, are locally quite thick and are of economic importance. As indicated by drill hole data, the Blevin seam ranges from 10.0 to 14.5 feet thick. Although Bureau of Reclamation drill holes were not deep enough to penetrate the Emerson seam, geologic literature indicates that the seam ranges from approximately 10 to 25 feet thick. The Fort Union Formation is estimated to be 1,400 feet thick.

The Wasatch Formation unconformably overlies the Fort Union Formation and crops out in the northwest quarter of the study area. It consists of brown, coarse-grained sandstone, interbedded with gray and red shale.

A map showing the geologic formations and drill hole locations within the Lay Creek study site is presented as Drawing X-400-125 on page 91. The map was adapted from E. T. Hancock, USGS Bulletin 757.

Drawing X-400-126 on page 92 includes a geologic section of coal beds in the Lay Creek area. Information from USGS drill holes, LSE-1 through LSE-4, was added to clarify the section. For additional information concerning these drill holes, see USGS Open-File Report 78-365, by Michael E. Brownfield.

GEOLOGIC INVESTIGATIONS

Four Nx-size (3-inch diameter) core holes, designated DH-1 through DH-4, were drilled at the Lay Creek site by the Bureau of Reclamation. Hole depths ranged from 200.0 to 303.4 feet. Locations of the drill holes are shown on the geologic map, Drawing X-400-125 on page 91.

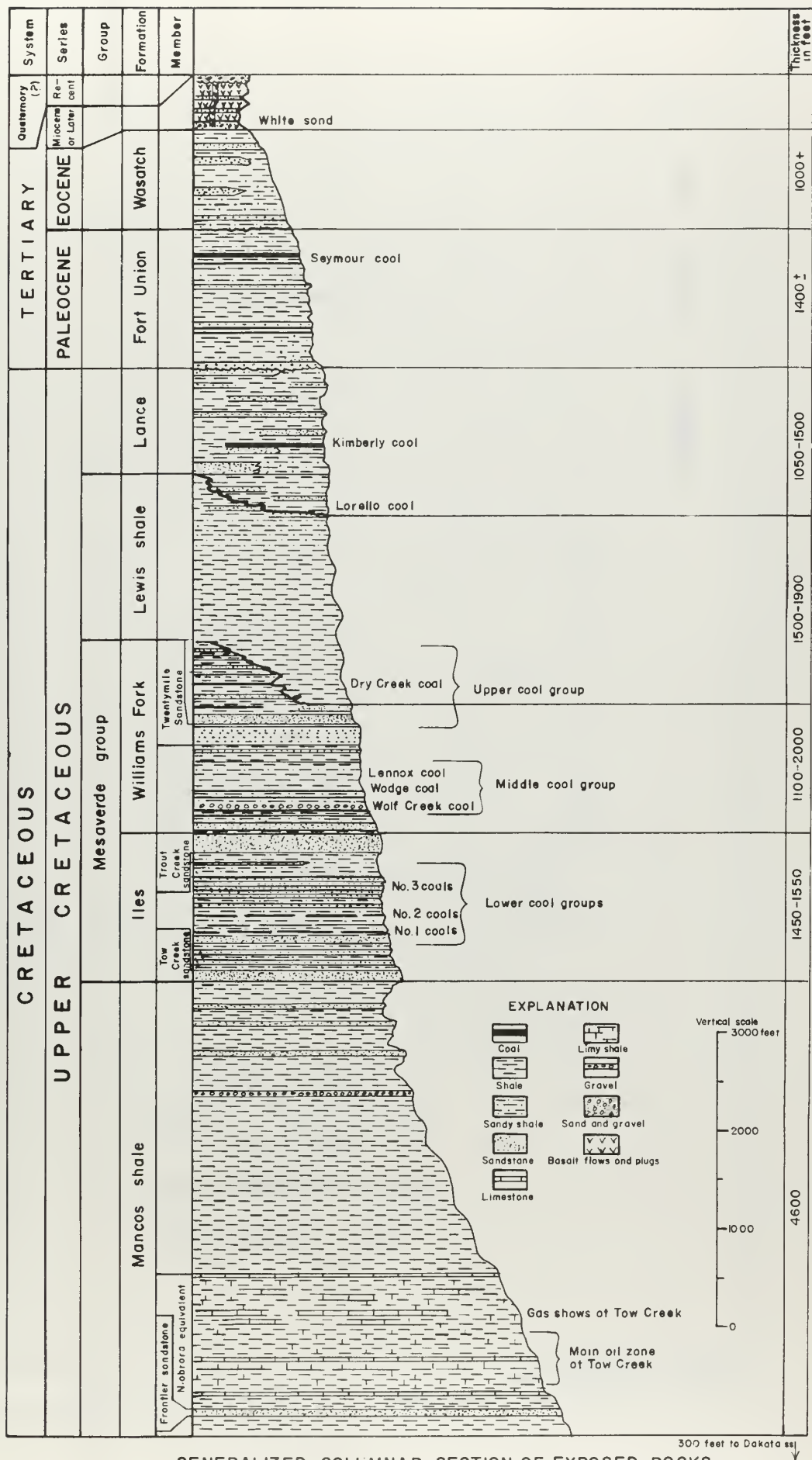
The holes were drilled using a skid-mounted Sprague and Henwood drill using recirculated clear water as the drilling medium. Cored materials were recovered with wire-line equipment. Temporary Nx casing was used through overburden soil and weathered rock near the surface. Additional casing was required in drill hole DH-2 when very weakly cemented sandstone was encountered at 152.0 feet. Casing was installed to 156.0 feet before drilling resumed. All temporary casing was removed from the holes after drilling was completed.

Upon completion of the drilling, recovered materials were logged by a Bureau of Reclamation geologist. All coal core samples were sealed in plastic bags immediately after removal from the core barrel and were shipped to the Geological Survey, in Denver, for analysis. The remainder of core samples were shipped to the Bureau of Reclamation's Soil Laboratory in Salt Lake City, Utah, for complete soils analysis.

Drill holes DH-1 through DH-3 were temporarily left open for geophysical logging by the Geological Survey. The holes were later sealed at the surface with a grout plug. Hole DH-4 encountered artesian flows and at the request of the Geological Survey was completed as a ground water observation well. Two hundred sixty-four and a half (264.5) feet of 2-inch PVC pipe, the bottom 80 feet perforated, was installed in the hole and grouted at the surface. The drill hole was marked at the surface with a 5-foot steel post to facilitate relocating the site. Representative samples of the major sandstone units, recovered from DH-4, were submitted to the Geological Survey, Water Resources Division, in Denver, for porosity and permeability tests.

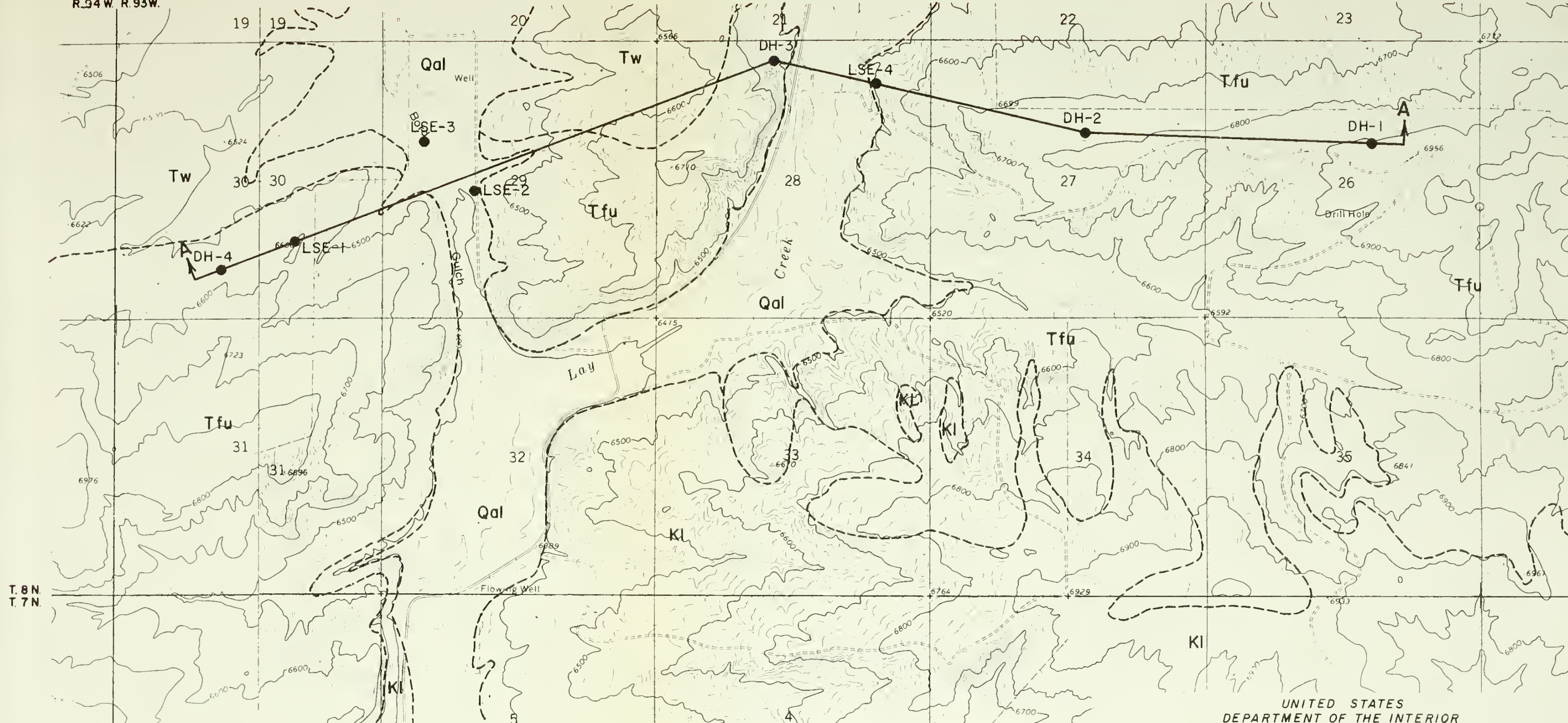
The geologic logs of drill holes DH-1 through DH-4 are included in this report on pages 93 through 103.

The shales, siltstones, and sandstones of the Wasatch and Fort Union Formations, which constitute overburden are weakly cemented to firm except for minor, scattered thin beds containing concretions or hard, well cemented siltstone and sandstone. All excavation would be classed as common, although, blasting would facilitate excavation of some horizons.

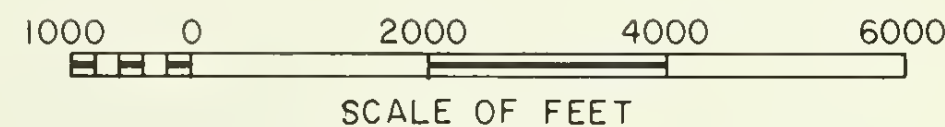


GENERALIZED COLUMNAR SECTION OF EXPOSED ROCKS
IN PARTS OF ROUTT AND MOFFAT COUNTIES, COLORADO

R. 34 W. R. 93 W.



T. 8 N.
T. 7 N.



EXPLANATION

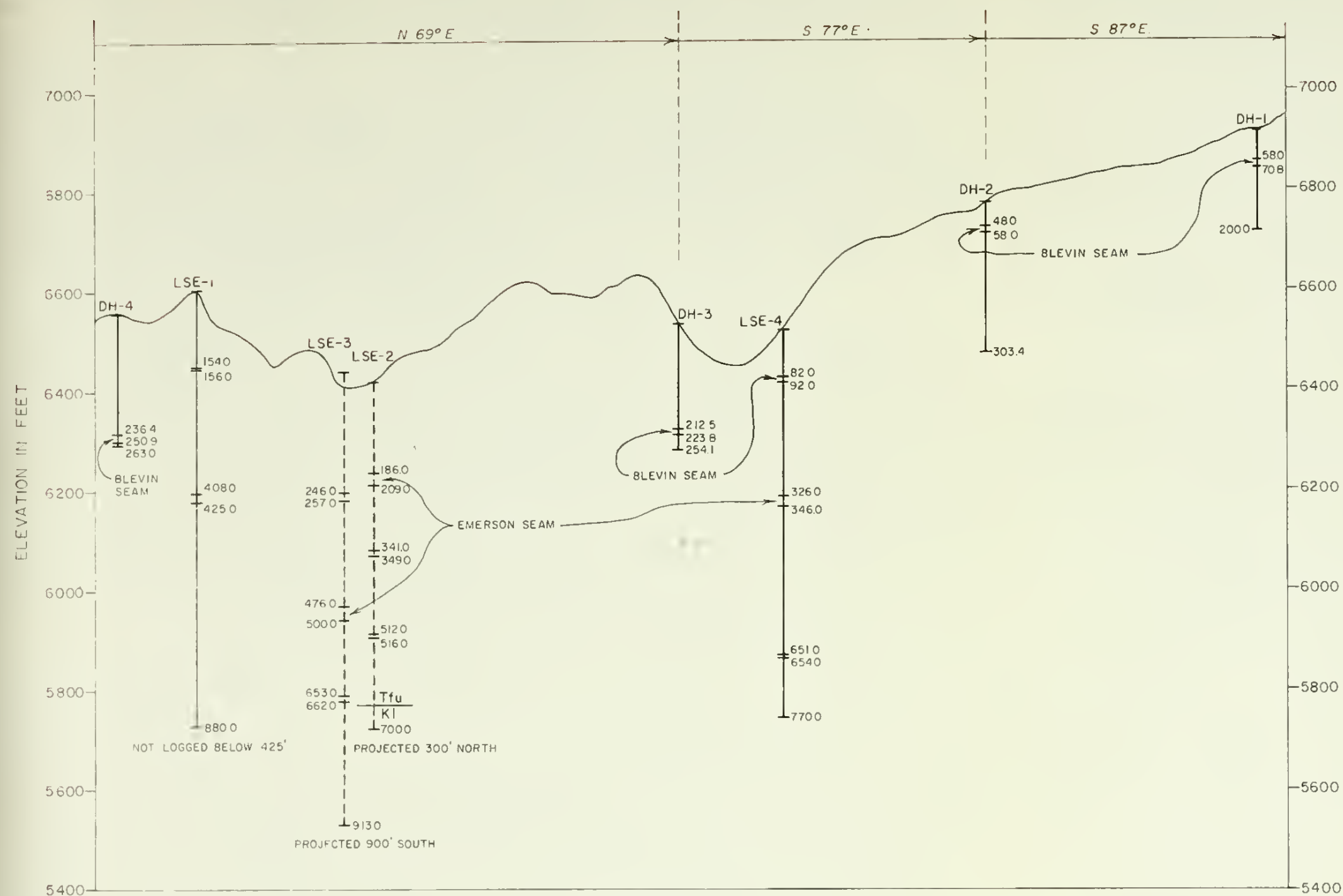
- Qal Quaternary Alluvium
- Tw Tertiary Wasatch Fm.
- Tfu Tertiary Fort Union Fm.
- Kl Cretaceous Lance Fm.
- - - - - Approximate geologic contact
- Vertical drill hole
- A — A Geologic cross section

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
TOPOGRAPHY

LAY CREEK SITE GEOLOGIC MAP

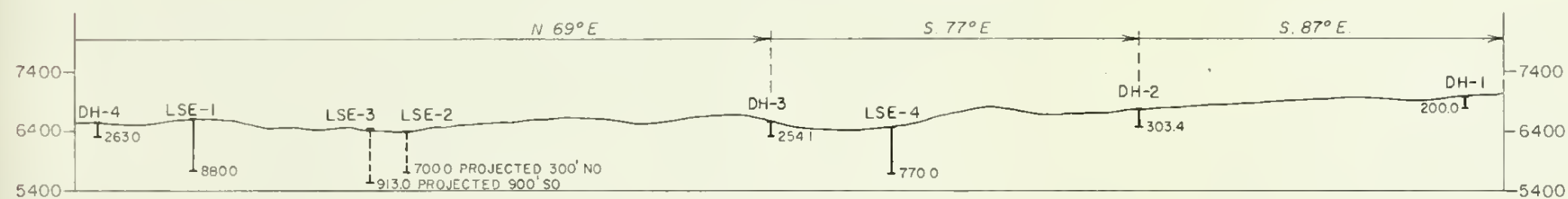
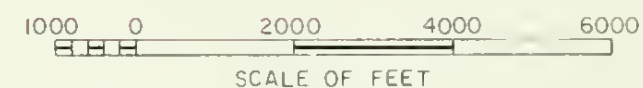
GEOLOGY APPROVED BY Charles F. Forvil DATE 4-10-79
REGIONAL GEOLOGIST

X-400-125



SECTION A-A

GEOLOGY APPROVED BY Charles M. Rowik DATE 4-10-79
REGIONAL GEOLOGIST



SECTION A-A
NATURAL SCALE

EXPLANATION

- Tfu FORT UNION FORMATION; Interbedded gray, fine to medium grained sandstone, light to dark gray siltstone, gray to black shale, and coal.
- 560
620 COAL SEAM, with indicated depths of top and bottom of coal seam.
- KI KARGE FORMATION; Interbedded gray shale, tan to light brown, soft, fine-grained sandstone, and a few coal bed.

SYMBOLS

- Tfu
KI Contact, dashed where approximate, queried where inferred.
- DH-1 Exploratory drill hole, dashed where projected to section line.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LAY CREEK SITE
GEOLOGIC SECTION A-A

X-400-126

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE EMRIA COAL STUDY PROJECT LAY CREEK SITE STATE COLORADO
 LOCATION SW¹, NE¹, Sec 26, T8N, R93W GROUND ELEV 6910.0 DIP (ANGLE FROM HORIZ) 90.0 Down
 HOLE No DH-1 COOROS N E TOTAL DEPTH 200.4 BEARING
 BEGUN 11-14-78 FINISHED 11-28-78 DEPTH OF OVERBURDEN 13.0
 DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED NOT MEASURED LOGGED BY D. GRUNDVIG LOG REVIEWED BY C. RORVIK

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	CORE RECOVERY %	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
	SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
NOTE: ALL MEASUREMENTS ARE FROM GROUND SURFACE AND ARE THE SAME AS THOSE USED BY THE DRILLER. HOLE HAS NOT SURVEYED. DEVIATION FROM VERTICAL (IF ANY) IS UNKNOWN. PURPOSE OF HOLE TO OBTAIN SAMPLES FOR DETERMINATION OVERBURDEN PROPERTIES. TO DETERMINE DEPTH AND THICKNESS OF COAT SEAM. DRILLING EQUIPMENT: SKID MOUNTED SPRAGUE AND HENWOOD. DRILLER: G. C. LARSEN, USBR DRILLING METHOD: HOLE HAS ADVANCED WITH NX DIAMOND CORE BIT. CORE RECOVERED WITH HIRE LINE. CASING RECORD: CS CS HOLE SIZE DEPTH (INCH) (FT.) (FT.) 4.0 10.0 10.0 4.0 13.0 13.0 4.0 22.0 23.0 4.0 23.0 23.0-200.4 DRILLING FLUID: CLEAR WATER, RE-CIRCULATED. DRILLING FLUID LOSSES (PCT): DEPTH LOSS 0.0 - 200 M 0.0				6297.0	10	10		0.0 - 13.0: CLAY APPROX. 80 PCT. MEDIUM PLASTIC FINES AND 20 PCT. FINE SAND. LIGHT TO DARK BROWN. MODERATE HCL REACTION (CL)
					10			13.0 - 42.0: SANDSTONE GRAY TO TAN. FINE TO MEDIUM GRAINED. MODERATE LIMONITE STAINING THROUGHOUT INTENSELY WEATHERED. NO HCL FRACTION. INTERNAL RECOVERED AS SAND AND FRAGMENTS. VERY LOW RECOVERY.
					6	20		42.0 - 50.6: SHALE GRAY TO BLACK. FISSILE. SOME LIMONITE STAINING ON PLANAR SURFACE. VERY SLIGHT TO NO HCL REACTION - CRUMBLY. CORE RECOVERED AS FRAGMENTS AND CORE LENGTHS TO 0.5 FEET. AVERAGE 0.1 TO 0.3 FEET.
					3	30		50.6 - 52.5: SANDSTONE GRAY TO YELLOWISH BROWN. FINE TO MEDIUM GRAINED. INTENSELY WEATHERED. EASILY CRUMBLED IN HAND. VERY SLIGHT HCL REACTION. RECOVERED AS FRAGMENTS AND CORE LENGTHS TO 0.4 FEET. AVERAGE 0.1 TO 0.3 FEET.
					10	40		52.5 - 58.0: SHALE GRAY TO BLACK. COMPACT. SLIGHTLY SANDY WITH MINOR AMOUNTS OF LIMONITE STAINING ON FRACTURES. VERY SLIGHT HCL REACTION. INTENSELY FRACTURED. CORE RECOVERED AS FRAGMENTS AND CORE LENGTHS TO 0.4 FEET. AVERAGE 0.1 TO 0.3 FEET.
				6888.0	69	50		58.0 - 70.8: COAL SAMPLE SUBMITTED TO USCS FOR ANALYSIS. SEE REPORT TEXT FOR DESCRIPTION.
				6859.4				
				6857.5				
				6852.0	78	60		70.8 - 84.5: SANDSTONE AND SHALE VARIED ZONES OF DARK GRAY TO BLACK. SANDY SHALE AND LIGHT GRAY SHALEY SANDSTONE. SANDSTONE IS FINE TO MEDIUM GRAINED AND BREAKS WITH LIGHT TO MODERATE HAMMER BLOW. VERY SLIGHT TO NO HCL REACTION. MOST CORE BREAKS ARE CLEAN AND APPROXIMATELY PERPENDICULAR TO CORE AXIS. SUSPECT SOME MECHANICAL BREAKAGE DURING DRILLING. CORE LENGTHS AVERAGE 0.2 TO 0.4 FEET. FEW SCATTERED FRAGMENTED INTERVALS.
			COAL	6839.2	93	70		84.5 - 127.3: SANDSTONE LIGHT GRAY TO TAN WITH MINOR AMOUNTS OF LIMONITE. STAINING (SPOTS). SLIGHT HCL REACTION.
				6825.5	100	80		127.3 - 110.8: FINE GRAINED, SILTY, CRUMBLES EASILY IN HAND-RECOVERED AS SAND. FRAGMENTS AND LENGTHS TO 0.6 FEET, AVERAGE 0.1 TO 0.3 FEET.
					43	90		

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 4

FEATURE <u>EMRIA COAL STUDY</u>		PROJECT <u>LAY CREEK SITE</u>		STATE <u>COLORADO</u>	
HOLE No <u>DH-1</u>		LOCATION <u>SW 1/4, NE 1/4, Sec 26, T8N, R93W</u>		GROUND ELEV. <u>6910.0</u>	
CDDRS <u>N</u>		E		DIP (ANGLE FROM HORIZ.) <u>90.0 Down</u>	
BEGUN <u>11-14-78</u>		FINISHED <u>11-28-78</u>		DEPT OF OVERBURDEN <u>13.0</u>	
TOTAL DEPTH <u>200.4</u>		BEARING			
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED		NOT MEASURED		LOGGED BY <u>D. GRUNDVIG</u>	
				LDG REVIEWED BY <u>C. RORVICK</u>	

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	CORE RECOVERY %	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
	SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
DRILL SITE: ELEVATION 6910. HIGH MOUNTAIN DESERT. SNOW PACKED, MODERATE VEGETAL COVER (SAGEBUSH, GRASS). HOLE COMPLETION: AFTER GEOPHYSICAL LOGGING BY USGS. HOLE WAS SEALED WITH GROUT PLUG.					3			
				6799.2	93	110		110.8 - 115.3: FINE TO MEDIUM GRAINED FIRM TO MODERATELY HARD - LENGTHS CANNOT BE BROKEN IN HAND. REQUIRE LIGHT TO MODERATE HAMMER BLOW. LENGTHS TO 1.5 FEET. AVERAGE LESS THAN A FOOT.
					19	120		115.3 - 127.3: SEE DESCRIPTION OF INTERVAL 84.5 - 110.8.
				6782.7	73	130		127.1 - 135.2: SHALE DARK GRAY TO BLACK. CARBONACEOUS IN PART. GENERALLY FIRM EXCEPT 127.1 - 128.8 WHICH IS CRUMBLY. NO HCL REACTION. RECOVERED AS FRAGMENTS AND LENGTHS TO 0.4 FEET. AVERAGE 0.2 TO 0.3 FEET.
				6774.8	96	140		135.2 - 200.4 SANDSTONE LIGHT TO DARK GRAY. FINE TO MEDIUM GRAINED WITH PAPER-THIN. BLACK. NEARLY HORIZONTAL SEAMS THROUGHOUT. SLIGHT HCL REACTION. MODERATE HARD EXCEPT 175.3 - 185.0 WHICH IS CRUMBLY AND SOMEWHAT SHALEY. INTERNAL 193.9 - 195.0 CONGLOMERATIC. CORE RECOVERED AS SAND FRAGMENTS. AND LENGTHS TO 2.4 FEET. AVERAGE LESS THAN 1.0 FEET.
					96	150		
					100	160		
					100	170		
					64	180		
					93	190		
			6709.6	100	200			STRATIGRAPHY 0.0 - 13.0: QUATERNARY SLOPASH 13.0 - 200.4: TERTIARY FORT UNION FORMATION

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE <u>EMRIA COAL STUDY</u>		PROJECT <u>LAY CREEK SITE</u>		STATE <u>COLORADO</u>																					
HOLE No. <u>DH-2</u>	LOCATION <u>SW 1/4, NE 1/4, Sec 27, T8N, R93W</u>	GROUND ELEV. <u>6770.0</u>	DIP (ANGLE FROM HORIZ.) <u>90° DOWN</u>																						
BEGUN <u>11-29-78</u>	COORDS <u>N 1-25-79 E</u>	DEPTH OF OVERBURDEN <u>25.9</u>	TOTAL DEPTH <u>303.4</u>	BEARING																					
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED		NOT MEASURED		LOGGED BY <u>D. E. GRUNDTVIG</u>																					
				LOG REVIEWED BY <u>C. RORVIK</u>																					
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	CORE RECOVERY %	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION																	
	SUITABLE	LIMITED SUITABILITY	UNSUITABLE																						
NOTE: ALL MEASUREMENTS ARE FROM GROUND SURFACE AND ARE THE SAME AS THOSE USED BY THE DRILLER. HOLE HAS NOT SURVEYED. DEVIATION FROM VERTICAL (IF ANY) IS UNKNOWN. PURPOSE OF HOLE TO OBTAIN SAMPLES FOR DETERMINATION OVERBURDEN PROPERTIES. TO DETERMINE DEPTH AND THICKNESS OF COAT SEAM. DRILLING EQUIPMENT: SKID MOUNTED SPRAGUE AND HENWOOD. DRILLER: G. C. LARSEN, USBR DRILLING METHOD: HOLE HAS ADVANCED WITH NX DIAMOND CORE BIT. CORE RECOVERED WITH HIRE LINE. CASING RECORD: <table border="1"> <thead> <tr> <th>CS SIZE (INCH)</th> <th>CS DEPTH (FT.)</th> <th>HOLE DEPTH (FT.)</th> </tr> </thead> <tbody> <tr> <td>4.0</td> <td>10.0</td> <td>10.0</td> </tr> <tr> <td>4.0</td> <td>20.0</td> <td>20.0</td> </tr> <tr> <td>4.0</td> <td>20.0</td> <td>25.9-156.0</td> </tr> </tbody> </table> NOTE: ENCOUNTERED WEAKLY CEMENTED SAND AND BECAME STUCK IN HOLE AT 152.0 FT. REAMED OVER WIRE-LINE CASING TO 149.0 AND PULLED WIRE-LINE CASING. REMOVED REAMING SHOE FROM CASING. INSTALLED 4.0 INCH CASING TO 156.0 <table border="1"> <thead> <tr> <th>CS SIZE (INCH)</th> <th>CS DEPTH (FT.)</th> <th>HOLE DEPTH (FT.)</th> </tr> </thead> <tbody> <tr> <td>4.0</td> <td>156.0</td> <td>156.0-303.4</td> </tr> </tbody> </table>	CS SIZE (INCH)	CS DEPTH (FT.)	HOLE DEPTH (FT.)	4.0	10.0	10.0	4.0	20.0	20.0	4.0	20.0	25.9-156.0	CS SIZE (INCH)	CS DEPTH (FT.)	HOLE DEPTH (FT.)	4.0	156.0	156.0-303.4				6744.1	10	0	0.0 - 25.9: CLAY APPROX. 80 PCT. MEDIUM PLASTIC FINES AND 20 PCT. FINE SAND. VERY SLIGHT TO NO HCL REACTION, GRAYISH BROWN TO BROWN. (CL)
	CS SIZE (INCH)	CS DEPTH (FT.)	HOLE DEPTH (FT.)																						
	4.0	10.0	10.0																						
	4.0	20.0	20.0																						
	4.0	20.0	25.9-156.0																						
	CS SIZE (INCH)	CS DEPTH (FT.)	HOLE DEPTH (FT.)																						
	4.0	156.0	156.0-303.4																						
						10		25.9 - 27.1: SANDSTONE GRAY, FINE TO MEDIUM GRAINED, LIMONITE STAINED SPOTS THROUGHOUT, MODERATE HCL REACTION. HARD, BREAKS WITH MODERATE HAMMER BLOW. CORE BREAKS ARE CLEAN AND APPROXIMATELY HORIZONTAL. SUSPECT SOME MECHANICAL BREAKAGE. RECOVERED AS 0.3 TO 0.5 FOOT LENGTHS.																	
						20		27.1 - 48.0: SHALE GRAY TO BLACK, CARBONACEOUS IN PART, LIMONITE STAINED THROUGHOUT. SOMEWHAT SANDY, SLIGHT HCL REACTION. SOFT, EASILY CRUMBLE IN HAND. BREAKS ARE APPROXIMATELY HORIZONTAL. RECOVERED AS FRAGMENTS AND LENGTHS TO 0.4, AVERAGE 0.1 TO 0.3 FEET.																	
						30		48.0 - 58.0: COAL SAMPLE SUBMITTED TO USGS FOR ANALYSIS. SEE REPORT TEXT FOR DESCRIPTION.																	
						35																			
						86																			
						94		58.0 - 75.0: SHALE DARK GRAY TO BLACK, SANDY, SLIGHT HCL REACTION FIRM, BREAKS WITH LIGHT TO MODERATE MANUAL PRESSURE. MAJORITY OF BREAKS ARE HORIZONTAL AND FREE OF MINERALIZATION. RECOVERED AS LENGTHS FROM 0.1 TO 3.2 FEET. MOST LESS THAN 0.6 FEET. CONTACT WITH SANDSTONE IS GRADATIONAL.																	
					6722.0	100		75.0 - 146.9: SANDSTONE SIGHT TO OAK GRAY, FINE TO MEDIUM GRAINED. PAPER THIN, HORIZONTAL, BLACK SEAMS AND MINOR SHALE SEAMS THROUGHOUT INTERVAL 75.0 - 129.5. SLIGHT HCL REACTION. SOFT TO FIRM. EASILY BROKEN IN HAND. CORE RECOVERED AS FRAGMENTS AND LENGTHS TO 1.0 FEET, MOSTLY 0.5.																	
				COAL		100																			
				6712.0	79																				
					94																				
				6695.0	17																				
					48																				
					83																				
EXPLANATION																									

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE <u>EMRIA COAL STUDY</u>		PROJECT <u>LAY CREEK SITE</u>		STATE <u>COLORADO</u>	
HOLE No <u>DH-2</u>	LOCATION <u>SW¹/₄, NE¹/₄, Sec 27, T8N R93W</u>	GROUND ELEV <u>6770.0</u>		DIP (ANGLE FROM HORIZ.) <u>90° DOWN</u>	
BEGUN <u>11-29-78</u>	COOROS <u>N</u>	FINISHED <u>1-25-79</u>	DEPTH OF OVERBURDEN <u>25.9</u>	TOTAL DEPTH <u>303.4</u>	BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED		NOT MEASURED		LOGGED BY <u>D. E. CRUNDTVIG</u>	
				LOG REVIEWED BY <u>C. RORVIK</u>	

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	CORE RECOVERY %	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION										
	SUITABLE	LIMITED SUITABILITY	UNSUITABLE															
DRILLING FLUID: CLEAR WATER, RECIRCULATED. DRILLING FLUID LOSSES (PCT.): <table style="width: 100%;"> <tr> <th style="width: 50%;">DEPTH</th> <th style="width: 50%;">LOSS</th> </tr> <tr> <td>0.0 - 36.0</td> <td>0.0</td> </tr> <tr> <td>36.0-56.0</td> <td>10.0</td> </tr> <tr> <td>56.0-156.0</td> <td>100.0</td> </tr> <tr> <td>156.0-303.4</td> <td>0.0</td> </tr> </table> DRILL SITE: ELEVATION 6770. HIGH MOUNTAIN DESERT. SNOW PACKED. MODERATE VEGETAL COVER (SAGEBRUSH, GRASSES) HOLE COMPLETION: AFTER GEOPHYSICAL LOGGING BY USGS. HOLE WAS SEALED WITH GROUT PLUG.	DEPTH	LOSS	0.0 - 36.0	0.0	36.0-56.0	10.0	56.0-156.0	100.0	156.0-303.4	0.0				6623.1	83	110		146.9 - 166.5: NO RECOVERY RECORDED ON DRILLER'S REPORT AS SAND.
	DEPTH	LOSS																
	0.0 - 36.0	0.0																
	36.0-56.0	10.0																
	56.0-156.0	100.0																
	156.0-303.4	0.0																
				6603.5	84	120												
				6592.7	85	130												
					78	140												
					100	150												
				0	160													
				36	170													
				55	180													
				72	190													
				85	200													

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE	EMRIA COAL STUDY		PROJECT	LAY CREEK SITE		STATE	COLORADO	
HOLE No	DH-2		LOCATION	SW 1/4, NE 1/4, Sec 27, T8N, R93W		GROUND ELEV	6770.0	
	COORDS		N	E		DIP (ANGLE FROM HORIZ.)	90° DOWN	
BEGUN	11-29-78		FINISHED	1-25-79		DEPTH OF OVERBURDEN	25.9	
						TOTAL DEPTH	303.4	
						BEARING		
DEPTH AND ELEV OF WATER	NOT MEASURED		LOGGED BY	D. E. GRUNDTVIG		LOG REVIEWED BY	C. RORVIK	
LEVEL AND DATE MEASURED								

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	CORE RECOVERY %	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
	SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
				6565.1	85			204.9 - 217.5: SANDSTONE AND SHALE LIGHT TO DARK GRAY, FIRM HORIZONS AND LENSES OF SHALEY, FINE GRAINED SANDSTONE AND SANDY SHALE. DARK SPLOCHES AND THIN SHALE SEAMS THROUGHOUT. SLIGHT HCL REACTION. MOST BREAKS HORIZONTAL. CORE CAN BE BROKEN WITH MODERATE MANUAL PRESSURE. CORE RECOVERED AS FRAGMENTS AND LENGTHS TO 1.2 FEET, MOSTLY LESS THAN 0.6 FEET.
					83	210		
				6552.5				
					100	220		
					100	230		
					100	240		
					99	250		
					100	260		STRATIGRAPHY 0.0 - 25.9: QUATERNARY SLOPEWASH 25.9 - 303.4: TERTIARY FORT UNION FM.
					100	270		
					87	280		
					89	290		
					49	300		

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE EMRIA COAL STUDY		PROJECT LAY CREEK SITE		STATE COLORADO	
HOLE No DH-3		LOCATION NE 1/4, NW 1/4, SEC 28, T8N, R93W		GROUND ELEV. 6530.0	
COORDS N 2-8-79 E		DIP (ANGLE FROM HORIZ.) 90° DOWN		TOTAL DEPTH 254.1	
BEGUN 1-29-79		FINISHED 2-8-79		DEPTH OF OVERBURDEN 13.6	
DEPTH AND ELEV. OF WATER NOT MEASURED		LOGGED BY D. E. GRUNDVIG		LOG REVIEWED BY C. RORVIK	

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	CORE RECOVERY %	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION																										
	SUITABLE	LIMITED SUITABILITY	UNSUITABLE																															
NOTE: ALL MEASUREMENTS ARE FROM GROUND SURFACE AND ARE THE SAME AS THOSE USED BY THE DRILLER. HOLE WAS NOT SURVEYED. DEVIATION (IF ANY) FROM VERTICAL IS UNKNOWN. PURPOSE OF HOLE: TO OBTAIN SAMPLES FOR DETERMINATION OF OVERBURDEN PROPERTIES. TO DETERMINE DEPTH AND THICKNESS OF COAL SEAM. DRILLING EQUIPMENT: SKID-MOUNTED SPRAGUE AND HENWOOD. DRILLER: G. C. LARSEN, USBR DRILLING METHOD 0.0 - 10.4 DRIVE SAMPLE. 10.4 - 254.1 NX DIAMOND CORE BIT, CORE RECOVERED WITH WIRE LINE. DRILLING FLUID: CLEAR WATER, RECIRCULATED. DRILLING FLUID LOSSES (PCT.): <table style="width:100%;"> <tr> <th>DEPTH</th> <th>PERCENT</th> </tr> <tr> <td>0.0 - 84.4</td> <td>0.0</td> </tr> <tr> <td>84.4 - 94.4</td> <td>35.0</td> </tr> <tr> <td>94.4 - 135.3</td> <td>20.0</td> </tr> <tr> <td>135.3 - 155.3</td> <td>15.0</td> </tr> <tr> <td>155.3 - 254.1</td> <td>5.0</td> </tr> </table> CASING RECORD: <table style="width:100%;"> <tr> <th>CS</th> <th>DEPTH</th> <th>HOLE</th> </tr> <tr> <th>SIZE OF CS</th> <th>DEPTH</th> <th></th> </tr> <tr> <th>(INCH)</th> <th>(FEET)</th> <th>(FEET)</th> </tr> <tr> <td>---</td> <td>---</td> <td>10.4</td> </tr> <tr> <td>4.0</td> <td>10.4</td> <td>10.4 - 254.1</td> </tr> </table> DRILL SITE: ELEVATION 6530. HIGH MOUNTAIN DESERT. SNOW PACKED. MODERATE VEGETAL COVER (SAGEBRUSH, GRASSES) HOLE COMPLETION: AFTER GEOPHYSICAL LOGGING BY USGS. HOLE WAS SEALED WITH GROUT PLUG.	DEPTH	PERCENT	0.0 - 84.4	0.0	84.4 - 94.4	35.0	94.4 - 135.3	20.0	135.3 - 155.3	15.0	155.3 - 254.1	5.0	CS	DEPTH	HOLE	SIZE OF CS	DEPTH		(INCH)	(FEET)	(FEET)	---	---	10.4	4.0	10.4	10.4 - 254.1							0.0 13.6: SANDY CLAY APPROXIMATELY 70 PCT. MEDIUM PLASTIC FINES AND 30 PCT. FINE-GRAINED. ANGULAR SAND. NUMEROUS ROOT FIBERS IN UPPER HORIZON. TAN TO BROWN MODERATE HCL REACTION. (CL) 13.6 - 25.1: SHALE GRAY. WELL CEMENTED. FIRM. FISSILITY POORLY DEVELOPED. BEDDING PLANES ARE DISTINCT. FE STAINING AND APPROXIMATELY HORIZONTAL. SLIGHT HCL REACTION. GRADATIONAL CONTACT WITH SANDSTONE BELOW. CORE RECOVERED AS FRAGMENTS AND LENGTHS FROM 0.1-0.3 FT. 25.1 - 28.6: SANDSTONE GRAY. FINE-GRAINED. SUBANGULAR TO SUBROUNDED GRAINS. MODERATELY HARD. MODERATELY WELL CEMENTED. LOW PORESITY. SOME FE STAINING ON FRACTURE SURFACES WHICH ARE INCLINED APPROX. 30 AND 50 DEG. TO CORE AXIS. SOME HEALING OF FRACTURES HAS OCCURRED. OCCASIONAL SMALL LIMONITE STAINED CONCRETIONS. GRADATIONAL CONTACT WITH SHALE BELOW. CORE BREAKS WITH HEAVY MANUAL PRESSURE. RECOVERED AS FRAGMENTS AND LENGTHS 0.3-0.5 FT LONG. 28.6 - 38.7: SHALE DARK GRAY. WELL CEMENTED. FIRM FISSILITY POORLY DEVELOPED BEDDING PLANES INDISTINCT. VERY LITTLE FE STAINING. SLIGHT HCL REACTION SLICKENSIDE. INCLINED APPROX. 45 DEG. TO CORE AXIS. FOUND AT 34.4 FT. GRADATIONAL CONTACT WITH SANDSTONE UNIT BELOW. CORE RECOVERED AS FRAGMENTS AND LENGTHS 0.3-2.0 FT. LONG. AVERAGE LESS THAN 1.0 FT. 38.7 - 40.5: SANDSTONE FINE-GRAINED. WELL SORTED SUBANGULAR TO SUBROUNDED GRAINS. WELL CEMENTED. MODERATELY HARD ROUGH CORE SURFACE. HAS THE APPEARANCE OF SALT AND PEPPER BEDDING INDISTINCT. VERY LITTLE FE STAINING. MODERATE HCL REACTION. GRADATION CONTACT WITH SHALE BELOW. CORE BREAKS WITH LIGHT HAMMER BLOW. RECOVERED AS 0.3-0.9 FT. LENGTHS. MOSTLY 0.4-0.5. 40.5 - 47.4: SHALE GRAY TO DARK GRAY. SANDY IN PART FISSILITY POORLY DEVELOPED. BEDDING INDISTINCT. VERY LITTLE FE STAINING. SLIGHT HCL REACTION. GRADATIONAL CONTACT WITH SANDSTONE BELOW. CORE BREAKS EASILY IN HAND WITH MOST BREAKS HORIZONTAL. RECOVERED AS 0.2-0.8 FT. LENGTHS. MOSTLY 0.4-0.5. 47.4 - 55.0: SANDSTONE GRAY. FINE TO MEDIUM GRAINED. ANGULAR GRAINS. POORLY SORTED. WEAKLY CEMENTED. VERY POROUS. SOAKS UP WATER READILY. ROUGH CORE SURFACE. NO HCL REACTION. SHALEY FROM 50.4 TO 51.8. ABRUPT CONTACT WITH SHALE BELOW. CORE CRUMBLES OR BREAKS EASILY IN HAND. RECOVERED AS FRAGMENTS AND LENGTHS TO 2.2 FT.. FRAGMENTED FROM 50.5 55.0 - 65.2: SHALE DARK GRAY, SANDY IN PART. FISSILITY POORLY DEVELOPED. BEDDING INDISTINCT. FRESH - NO STAINING. FIRM, BREAKS IN HAND WITH MODERATE MANUAL PRESSURE. SLIGHT TO MODERATE HCL REACTION. GRADATIONAL CONTACT WITH SANDSTONE BELOW. RECOVERED AS 0.3-2.1 FT. LENGTHS, MOST LESS THAN 1.0 FT. 65.2 - 71.7: SANDSTONE DARK GRAY, FINE-GRAINED, EVEN TEXTURED. SUBANGULAR TO SUBROUNDED GRAINS, WELL SORTED. MODERATELY WELL CEMENTED, LOW POROSITY. NO FE STAINING, MODERATE HCL REACTION. GRADATIONAL CONTACT WITH SANDSTONE BELOW. CORE BREAKS WITH LIGHT HAMMER BLOW. AVERAGE RECOVERED LENGTHS LESS THAN 1.0 FT.
DEPTH	PERCENT																																	
0.0 - 84.4	0.0																																	
84.4 - 94.4	35.0																																	
94.4 - 135.3	20.0																																	
135.3 - 155.3	15.0																																	
155.3 - 254.1	5.0																																	
CS	DEPTH	HOLE																																
SIZE OF CS	DEPTH																																	
(INCH)	(FEET)	(FEET)																																
---	---	10.4																																
4.0	10.4	10.4 - 254.1																																

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE EMRIA COAL STUDY PROJECT LAY CREEK SITE STATE COLORADO
HOLE No DH-3 LOCATION NE 1/4, NW 1/4, Sec 28, T8N R93W GROUND ELEV 6530.0 DIP (ANGLE FROM HORIZ) 90° down
BEGUN 1-29-79 COOROS N E FINISHED 2-8-79 DEPTH OF OVERBURDEN 13.6 TOTAL DEPTH 254.1 BEARING
DEPTH AND ELEV OF WATER NOT MEASURED LOGGED BY D. E. GRUNDTVIG LOG REVIEWED BY C. RORVIK

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	CORE RECOVERY %	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONOITION
	SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
				6365.9	100			71.7 - 86.9: SANDSTONE LIGHT TO DARK GRAY, SALT AND PEPPER APPEARANCE FINE TO MEDIUM-GRAINED. POORLY SORTED, WEAKLY CEMENTED, SOFT AND CRUMBLY IN PART. HIGHLY POROUS - READILY ACCEPTS WATER. ROUGH CORE SURFACE. THIN, BLACK LAMINATIONS, INCLINED 20-50 DEG. TO CORE AXIS THROUGHOUT. MODERATE TO STRONG HCL REACTION, GRADATIONAL CONTACT WITH UNIT BELOW. RECOVERED AS 0.7-1.3 FT. LENGTHS. 86.9 - 164.1: SANDSTONE AND SHALE INTERBEDDED SANDSTONE AND SHALE. SANDSTONE IS DARK GRAY, FINE TO MEDIUM-GRAINED, MODERATELY WELL CEMENTED, MODERATE HCL REACTION, CONTAINS THIN, BLACK LAMINATIONS INCLINED APPROX. 30 DEG. TO CORE AXIS. SHALE IS LIGHT TO DARK GRAY THINBEDDED, SANDY IN PART. FISSILITY WELL DEVELOPED, SLIGHT TO NO HCL REACTION. LIGHT FE STAINING (LIMONITE) ON SOME SURFACES INTERVAL IS PREDOMINANTLY SANDSTONE FROM 123.9-164.1. ABRUPT CONTACT WITH SANDSTONE BELOW. ALL CORE BREAKS IN HAND. RECOVERED AS LENGTHS FROM 0.3 TO 2.8 FT., AVERAGE APPROX. 1.0 FT.
					78			
					99	110		
					100	120		
					100	130		
					100	140		
					98	150		
					97	160		
				6345.8	37	170		164.1 - 184.2: SANDSTONE LIGHT GRAY, FINE TO MEDIUM-GRAINED ANGULAR TO SUBANGULAR GRAINS. POORLY SORTED, WEAKLY CEMENTED. CORE HAS A SALT AND PEPPER APPEARANCE. ROUGH CORE SURFACE, VERY POROUS - READILY ACCEPTS WATER. CARHONACEOUS FROM 187.1-187.3 SLIGHT HCL REACTION. ABRUPT CONTACT WITH UNIT BELOW. CORE IS EASILY CRUMBLED IN HAND. RECOVERED AS FRAGMENTS AND LENGTHS TO 2.0, MOST LESS THAN 1.0 FT.
					35	180		
					100	190		
					98			184.2 - 200.1: SANDSTONE AND SHALE SEE DESCRIPTION OF INTERVAL 86.9-164.1 CORE RECOVERED AS 0.1-1.9 FT. LENGTHS, AVERAGE APPROX. 0.7 FT.

EXPLANATION

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE <u>EMRIA COAL STUDY</u>		PROJECT <u>LAY CREEK SITE</u>		STATE <u>COLORADO</u>				
HOLE No. <u>DH-3</u>		LOCATION <u>NE 1/4, NW 1/4, Sec 28, T8N, R93W</u>		GROUND ELEV <u>6530.0</u>				
BEGUN <u>1-29-79</u>		FINISHED <u>2-8-79</u>		OIP (ANGLE FROM HORIZ) <u>90° down</u>				
COOROS <u>N</u>		E <u>E</u>		TOTAL DEPTH <u>254.1</u>				
DEPTH AND ELEV OF WATER LEVEL AND DATE MEASURED <u>NOT MEASURED</u>		DEPTH OF OVERBURDEN <u>13.6</u>		BEARING				
LOGGED BY <u>D. E. GRUNVIG</u>		LOG REVIEWED BY <u>C. RORVIK</u>						
NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	CORE RECOVERY %	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
	SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
				6329.9				200.1 - 210.9: SANDSTONE WHITE TO LIGHT GRAY, FINE TO MEDIUM-GRAINED, SUBANGULAR TO SUBROUNDED GRAINS, MODERATELY SOFT TO MODERATELY HARD, LOW TO MODERATE POROSITY, SLIGHT TO MODERATE HCL REACTION. INTERVAL CONTAINS NUMEROUS THIN, BLACK LAMINATIONS AND SWIRLS. LAMINATIONS ARE INCLINED APPROX. 30 DEG. TO CORE AXIS. JOINTS INCLINED APPROX 25.50, AND 70 DEG. TO CORE AXIS. SOME DENDRITES (PYROLUSITE) DEVELOPED ON SOME FRACTURES GRADATIONAL CONTACT WITH SHALE BELOW. CORE BREAKS WITH LIGHT TO HEAVY MANUAL PRESSURE. RECOVERED AS 0.3-1.9 FT. LENGTHS, MOST ARE GREATER THAN 1.0 FT.
				6319.1		210		
			COAL	6317.5				
				6306.2		220		210.9 - 212.5: SHALE DARK GRAY TO BLACK, CARBONACEOUS IN PART. THIN BEDDED, FISSILITY WELL DEVELOPED, BEDDING DISTINCT, NO HCL REACTION, CRUMBLY, RECOVERED AS FRAGMENTS AND LENGTHS TO 0.4 FT., MOST ARE GREATER THAN 0.2 FT.
				6304.6		230		212.5 - 223.8: COAL SAMPLE SUBMITTED TO USGS FOR ANALYSIS. SEE REPORT TEXT FOR DESCRIPTION.
						240		223.8 - 225.4: SHALE SEE DESCRIPTION OF INTERVAL 210.9-212.5
						250		225.4 - 254.1: SILTSTONE DARK GRAY, SANDY AND SHALY IN PART. VERY HARD ONSE, CORE SURFACE SMOOTH. SOME THIN, BLACK LAMINATIONS IN UPPER PART OF UNIT. VERY LOW POROSITY, SLIGHT HCL REACTION. LEAF IMPRESSION FOUND AT 240.0. CORE BREAKS WITH LIGHT TO MODERATE HAMMER BLOW. RECOVERED AS 0.1-1.3 FT., MOST ARE GREATER THAN 0.5 FT.
				6275.9		260		STRATIGRAPHY 0.0 - 13.6: QUATERNARY SLOPEWASH 13.6 - 254.1: TERTIARY FORT UNION FM.
						270		T.O. 254.1
						280		
						290		
EXPLANATION								

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE EMRIA COAL STUDY PROJECT LAY CREEK SITE STATE COLORADO
 HOLE No DH-4 LOCATION SE 1/4, SW 1/4, Sec 30, T8N, R93W GROUND ELEV. 6540.0 DIP (ANGLE FROM HORIZ.) 90° Down
 BEGUN 2-12-79 COORDS N E FINISHED 2-26-79 DEPTH OF OVERBURDEN 13.0 TOTAL DEPTH 263.5 BEARING
 DEPTH AND ELEV. OF WATER SEE NOTES LOGGED BY D. E. GRUNDVIG LOG REVIEWED BY C. RORVIK

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	CORE RECOVERY %	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
	SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
NOTE: ALL MEASUREMENTS ARE FROM GROUND SURFACE AND ARE THE SAME AS THOSE USED BY THE DRILLER. HOLE WAS NOT SURVEYED. DEVIATION (IF ANY) FROM VERTICAL IS UNKNOWN.				6538.0	25			0.0 - 2.0: SANDY CLAY APPROXIMATELY 70 PCT. MEDIUM PLASTIC FINES AND 30 PCT. FINE-GRAINED, ANGULAR SAND, NUMEROUS ROOT FIBERS IN UPPER HORIZONS, TAN TO BROWN. MODERATE HCL REACTION. (CL)
PURPOSE OF HOLE: TO OBTAIN SAMPLES FOR DETERMINATION OF OVERBURDEN PROPERTIES. TO DETERMINE DEPTH AND THICKNESS OF COAL SEAM.				6527.0	93	10		2.0 - 13.0: CLAYEY SAND RECOVERED AS APPROXIMATELY 80 PCT. MEDIUM TO COARSE-GRAINED, ANGULAR TO SUBROUNDED SAND AND 20 PCT. LOW TO MEDIUM PLASTIC FINES. YELLOWISH BROWN MODERATE HCL REACTION. (SC)
DRILLING EQUIPMENT: SKID-MOUNTED SPRAGUE AND HENWOOD.				6517.4	96	20		13.0 - 22.6: SILTSTONE GRAY TO YELLOWISH BROWN. LIMONITE AND MANGANESE STAINED IN PART. HARD, DENSE, CORE SURFACE SMOOTH, BEDDING INDISTINCT. LOW POROSITY SLIGHT TO MODERATE HCL REACTION. MOST CORE BREAKS ARE APPROX. HORIZONTAL. CORE BREAKS WITH MODERATE MANUAL PRESSURE. RECOVERED AS FRAGMENTS AND LENGTHS TO 1.3 FT., AVERAGE 0.1-0.3 FT.
DRILLER: G. C. LARSEN, USBR				6503.5	98	30		22.6 - 36.5: SHALE DARK GRAY TO BLACK, SANDY IN PART, FISSILITY POORLY DEVELOPED, BEDDING INDISTINCT. VERY SLIGHT FE STAINING ON FRACTURE SURFACES. SLIGHT HCL REACTION. CORE IS FIRM TO CRUMBLY. MOST BREAKS ARE HORIZONTAL. RECOVERED AS FRAGMENTS AND LENGTHS TO 0.9, AVERAGE 0.1-0.4 FT.
DRILLING METHOD: 0.0-13.0 DRIVE SAMPLE 13.0-263.5 NX OIA-MOND CORE BIT. CORE RECOVERED WITH WIRE LINE.				6492.8	100	40		36.5 - 47.2: SANDSTONE LIGHT TO DARK GRAY, FINE-GRAINED, EVEN TEXTURED SUBROUNDED TO SUBANGULAR GRAINS, WELL SORTED, WELL CEMENTED. HARD, LOW POROSITY. MODERATE TO STRONG HCL REACTION. GRADATIONAL, CONTACT WITH SHALE BELOW. CORE BREAKS APPROX. HORIZONTAL WITH MODERATE HAMMER BLOW. RECOVERED AS LENGTHS FROM 0.1-1.3 FT. MOST LESS THAN 0.7 FT.
DRILLING FLUID: CLEAR WATER RECIRCULATED.				6483.0	98	50		47.2 - 57.0: SHALE DARK GRAY TO BLACK. FISSILITY WELL DEVELOPED, CRUMBLY, MOST BREAKS ARE HORIZONTAL AND FREE OF STAINING. SLIGHT TO MODERATE HCL REACTION. GRADATIONAL CONTACT WITH SANDSTONE BELOW. RECOVERED AS 0.1-0.9 FT. LENGTHS. AVERAGE 0.1-0.3 FT.
DRILLING FLUID LOSSES (PCT.): DEPTH PERCENT 0.0-15.9 0.0 15.9-25.3 10.0 25.3-225.9 5.0 225.9-263.5 0.0				6473.7	100	60		57.0 - 66.3: SANDSTONE LIGHT GRAY, FINE-GRAINED, EVEN TEXTURED, WELL SORTED. MODERATELY WELL CEMENTED. LOW POROSITY THIN, BLACK LAMINATIONS. INCLINED APPROX. 30 DEG. TO CORE AXIS. IN SOME INTERVALS, CORE SURFACE AND BREAKS (HORIZONTAL) ARE FRESH. SLIGHT TO MODERATE HCL REACTION. GRADATIONAL CONTACT WITH SHALE BELOW. CORE BREAKS WITH MODERATE MANUAL PRESSURE. RECOVERED AS 0.2-1.1 FT. LENGTHS, AVERAGE 0.5-0.7 FT.
CASING RECORD CS DEPTH HOLE SIZE OF CS DEPTH (INCH) (FEET) (FEET) --- 13.0 4.0 12.2 13.0 - 263.5					100	70		66.3 - 120.4: SILTSTONE AND SHALE INTERBEDDED DARK GRAY SHALE AND SILTSTONE. FISSILITY OF SHALE IS WELL DEVELOPED, CRUMBLY. MOST BREAKS ARE HORIZONTAL AND FREE OF STAINING. HCL REACTION, NONE TO SLIGHT. GRADATIONAL CONTACTS WITH SILTSTONE. SHALE BREAKS OR CRUMBLES EASILY IN HAND. RECOVERED AS CHIPS, FRAGMENTS AND LENGTHS TO 1.1 FT., MOST ARE LESS THAN 0.3 FT.
DRILL SITE: ELEVATION 6540. HIGH MOUNTAIN DESERT, SNOW PACKED. MODERATE VEGETAL COVER (SAGE-BRUSH, GRASSES)					88	80		SILTSTONE IS MODERATELY WELL CEMENTED, HARD, AND DENSE. CORE SURFACE IS SMOOTH, LOW POROSITY. SLIGHT TO MODERATE HCL REACTION. MOST CORE BREAKS WITH LIGHT HAMMER TAP. SILTSTONE RECOVERED AS 0.1-2.1 FT. LENGTHS, AVERAGE IS LESS THAN 1.0 FT.
HOLE COMPLETION AT USGS REQUEST, DRILL HOLE WAS COMPLETED AS AN OBSERVATION WELL. 264.5 FEET OF PLASTIC PIPE (BOTTOM 80 FT. PERFORATED) WAS INSTALLED IN HOLE.					95	90		INTERVALS ARE FURTHER DEFINED BELOW. SHALE: 66.3-69.5, 74.0-82.1, 84.8-92.5, 94.6-95.5, and 111.3-120.4. SILTSTONE: 69.5-74.0, 82.1-84.8, 92.5-94.0, AND 95.5-111.3.
					100			

EXPLANATION

SHEET 2 OF 3

[illegible]

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE <u>EMRIA COAL STUDY</u>		PROJECT <u>LAY CREEK SITE</u>		STATE <u>COLORADO</u>	
HOLE No <u>DH-4</u>	LOCATION <u>SE 1/4, SW 1/4, SEC 30, T8N, R93W</u>	GROUND ELEV <u>6540.0</u>		DIP (ANGLE FROM HORIZ.) <u>90° DOWN</u>	
BEGUN <u>2-12-79</u>	FINISHED <u>2-26-79</u>	DEPTH OF OVERBURDEN <u>13.0</u>		TOTAL DEPTH <u>263.5</u>	
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED <u>SEE NOTES</u>		LOGGED BY <u>D. E. GRUNDVIG</u>		LOG REVIEWED BY <u>C. RORVIK</u>	

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS	SUITABILITY OF OVERBURDEN			ELEVATION (FEET)	CORE RECOVERY %	DEPTH (FEET)	GRAPHIC LOG	CLASSIFICATION AND PHYSICAL CONDITION
	SUITABLE	LIMITED SUITABILITY	UNSUITABLE					
					99			
					85	210		SILTSTONE INTERVAL 204.9-206.4. CORE RECOVERED AS FRAGMENTS AND LENGTHS TO 0.5 FT. AVERAGE LESS THAN 0.2 FT.
					98	220		
				6316.6	98			223.2 - 235.0: SANDSTONE WHITE TO LIGHT GRAY, FINE-GRAINED, SUBANGULAR TO SUBROUNDED GRAINS, MODERATELY HARD. LOW POROSITY, SLIGHT HCL REACTION. INTERVAL CONTAINS NUMEROUS THIN, BLACK LAMINATIONS INCLINED APPROX. 20 DEG. TO CORE AXIS. FRACTURE SURFACES ARE APPROX. HORIZONTAL AND FREE OF ANY STAINING. GRADATIONAL CONTACT WITH SHALE BELOW. CORE BREAKS WITH LIGHT TO HEAVY MANUAL PRESSURE. RECOVERED AS 0.3-1.1 FT LENGTHS.
					100	230		
				6305.0 6303.6				235.0 - 236.4: THINBEDDED, FISSILITY BLACK, CARBONACEOUS, WELL DEVELOPED. CRUMBLY, NO HCL REACTION. RECOVERED AS CHIPS AND FRAGMENTS TO 0.2 FT.
			COAL		99	240		236.4 - 250.9: COAL SAMPLE SUBMITTED TO USGS FOR ANALYSIS. SEE REPORT TEXT FOR DESCRIPTION.
					100	250		250.9 - 251.6: SHALE SEE DESCRIPTION OF INTERVAL 235.0-236.4.
				6289.1				251.6 - 263.5: SANDSTONE SEE DESCRIPTION OF INTERVAL 223.2-236.4. NUMEROUS THIN, BLACK, HORIZONTAL LAMINATIONS. MODERATE TO STRONG HCL REACTION. RECOVERED AS 0.3-2.4 FT. LENGTHS, MOST ARE GREATER THAN 1.0 FT.
					100	260		
				6276				STRAITIGRAPHY 0.0 - 13.0: QUATERNARY SLOPEWASH 13.0 - 263.5: TERTIARY FORT UNION FM.
						270		
						280		
						290		

EXPLANATION

GEOLOGICAL STUDY OF THE
LAY CREEK PORTION OF THE
YAMPA COAL FIELD

United States Department of the Interior
Geological Survey
Conservation Division

Written by
M. E. Brownfield
1975-76

GEOLOGICAL STUDY OF THE
LAY CREEK PORTION OF THE
YAMPA COAL FIELD

Geology of the Lay Creek Study Area

The Lay Creek Study Area is located in the Sand Wash Basin in the southern part of the Wyoming Basin physiographic province as defined by Fenneman (1931). Within the study area economic coal beds are present only in strata of Early Tertiary age. As a part of a more extensive geologic investigation the study area was mapped by Michael Brownfield as a part of the Lay and Lay SE quadrangles (fig. 1). A report on the geology and coal resources is in progress. Four holes were cored in the study area by the Bureau of Reclamation (figs. 1 and 2). The coal beds from these cores were sampled and submitted to J. R. Hatch, of the U.S. Geological Survey, for analysis.^{1/}

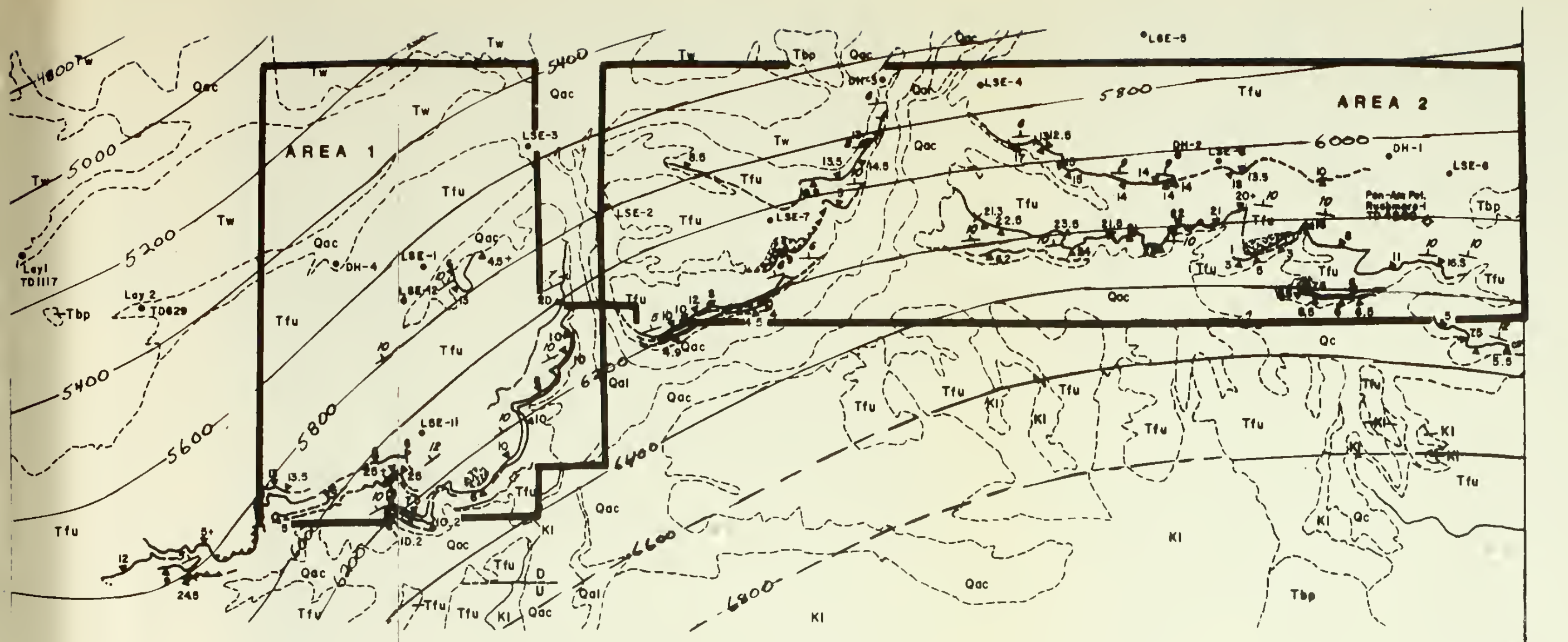
Geologic History

During much of Cretaceous time, the Sand Wash Basin was the site of marine deposition. By Late Cretaceous time sands from the west progressively pushed the strand line eastward. The Mesaverde Group and the Lance Formation are the result of sedimentation along the margins of regressing and transgressing Cretaceous seas. The Lewis Shale, which overlies the Mesaverde Group, represents a wedge of marine shale in the predominantly nonmarine Upper Cretaceous of northwest Colorado. Towards the end of Cretaceous time the foreland began to rise and the sea withdrew slowly towards the north and east.

During the deposition of the continental-fluvial Lance Formation the streams flowed eastward through the basin (Masters, 1961, p. 127). As the foreland continued to rise in the west until it was an active positive area, the Parks Range, to the east of the study area, had risen also. The uplift of the Park Range resulted in northward diversion of the drainage system. One large river system was established which flowed north, probably from the Sawatch Range (Tweto, 1975, p. 17). Another smaller one flowed east (probably from the Uintas), joining the larger system in the center of the Sand Wash Basin (Colson, 1969, p. 124).

The uplift of the Parks Range led to erosion along the basin edges and deposition of the Fort Union Formation in the central and northern part of the Sand Wash Basin. An extensive basal conglomerate marks the uplift of the Parks Range and the beginning of Paleocene deposition. The broad distribution of sandstones in the lower Fort Union indicates that the early streams were braided and had low sinuosity. The early streams ranged widely across the basin. Increase in sinuosity of Fort Union streams through time brought about initial stabilization of the

^{1/} Results from coal analysis were not received in time to incorporate them into this report.



GEOLOGIC MAP OF THE LAY CREEK STUDY AREA

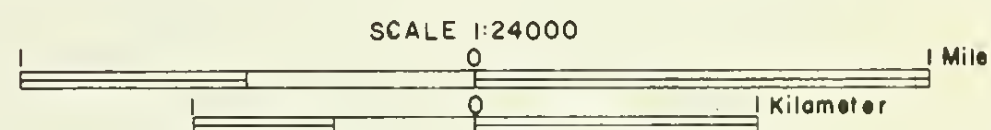


Figure 1

EXPLANATION

- Qal Alluvium
- Qc Colluvium
- Qac Alluvium, colluvium, undifferentiated
- Tbp Browns Park Formation
- Tw Wasatch Formation
- Tfu Fort Union Formation
- Kl Lance Formation

- CZ- COAL BED-Approximately located; dashed where inferred. Thickness in feet measured at triangle. CZ indicates carbonaceous shale beds containing very little coal: mapped locally for structural control

- BAKED AND FUSED STRATA

- CONTACT-Approximately located; dashed where inferred

- D
U
FAULT-Approximately located; dashed where inferred. D, downthrown side; U, upthrown side

- STRIKE AND DIP OF BEDS

- 6000- STRUCTURE CONTOURS-Drawn on basis of Fort Union Formation using surface data and drill-hole data. Short dashed where projected over land surface. Contour interval 200 feet

- ADIT

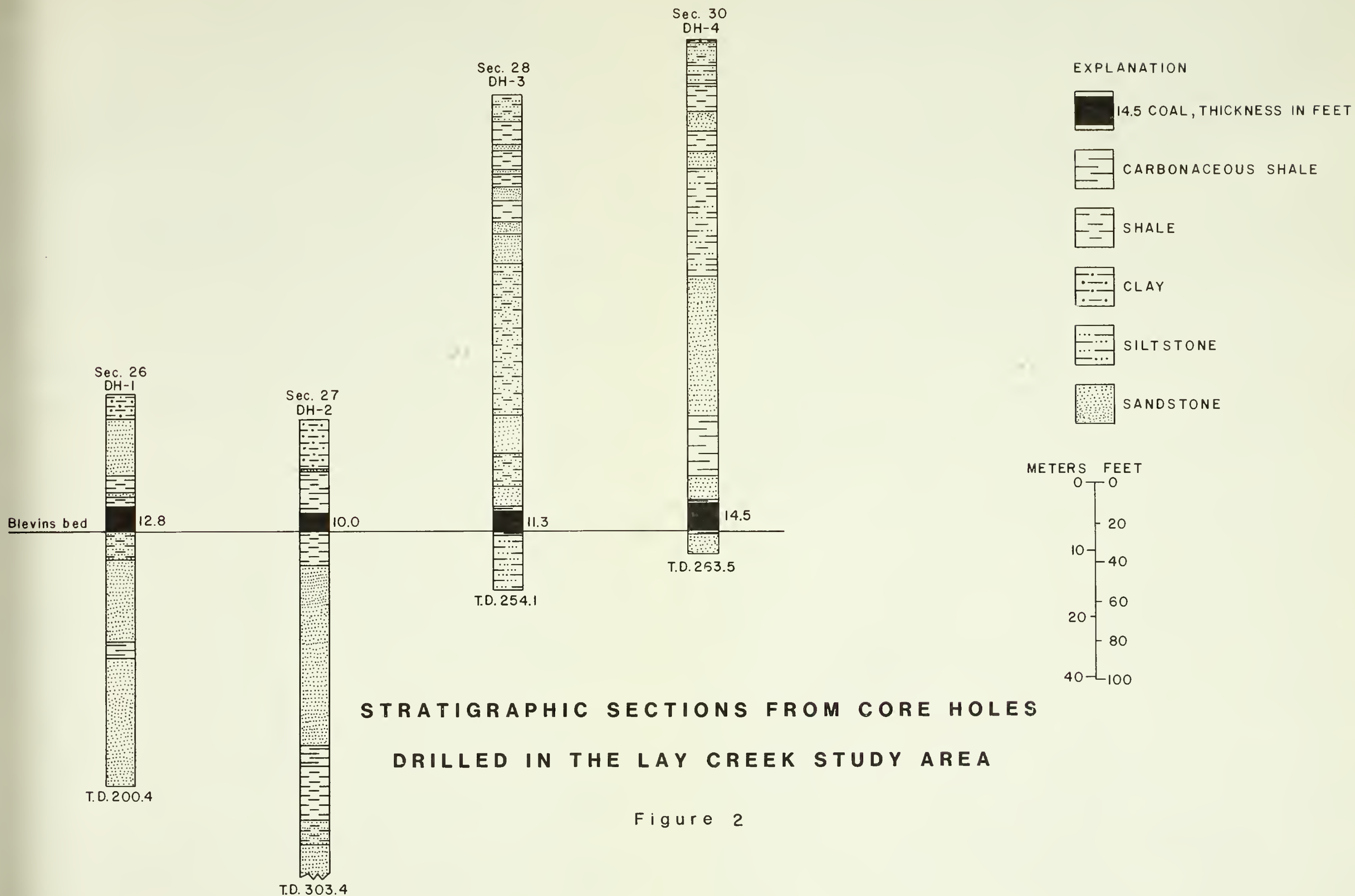
- X PROSPECT PIT

- LSE-8 USGS DRILL HOLE

- DH-2 BUREAU OF RECLAMATION CORE HOLE

- Pan-Am Pet DRY HOLE-Showing name of operator, Rushmore-1 Isasa, name, and total depth (TD) in feet TD 4200

- BOUNDARY EMRIA STUDY AREA



stream meander belts and caused the formation of extensive flood basins in which coal and thick deposits of silt and clay developed.

Deposition of the Fort Union Formation ended in the early Eocene when renewed tectonic activity caused the uplift of the White River Plateau and Uinta Mountains (Tweto, 1975, p. 3). Again the margins of the Sand Wash Basin were eroded and coarse sediments of the Wasatch Formation were deposited.

Coal Stratigraphy

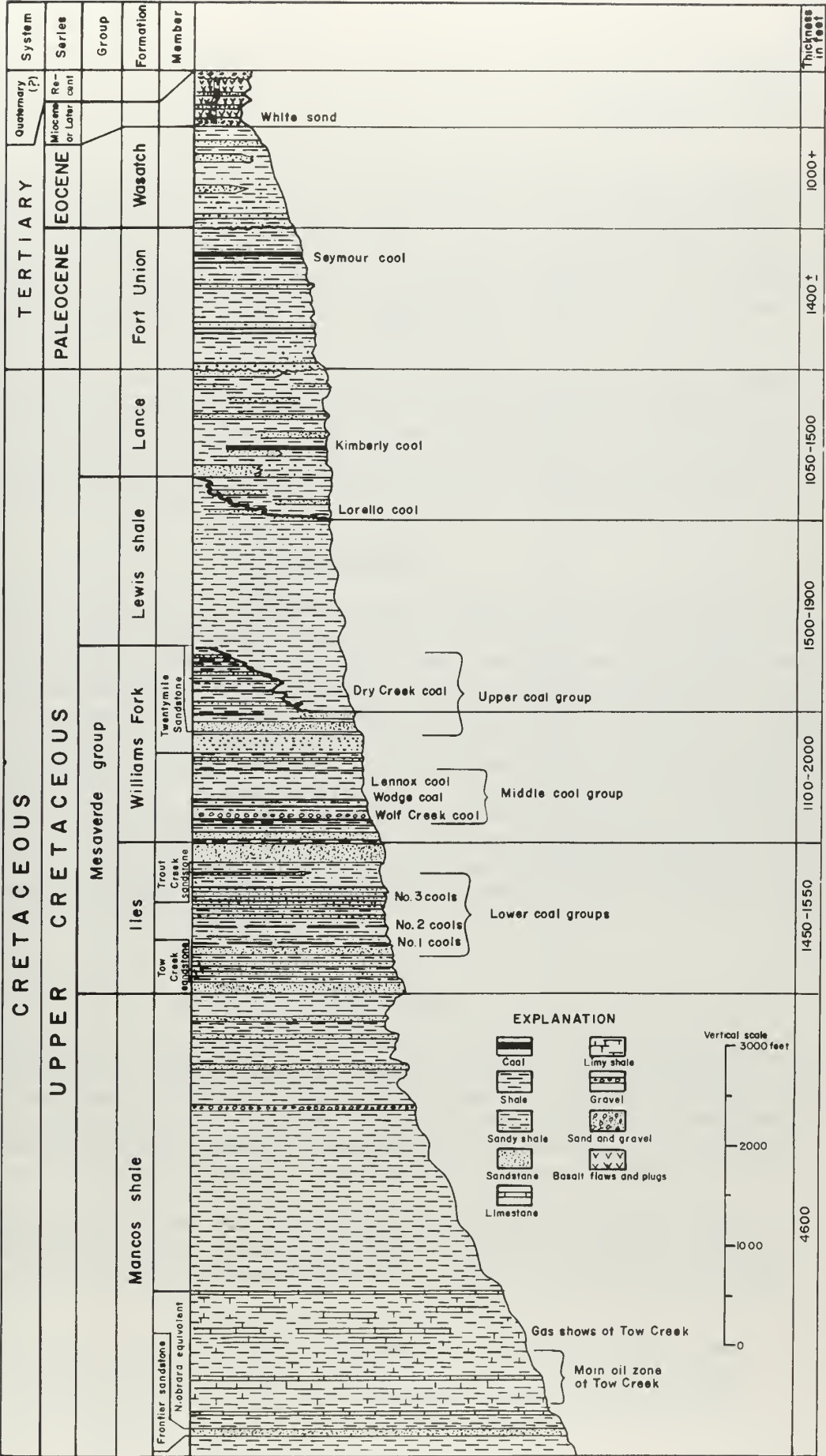
In northwest Colorado, coal beds of economic interest occur in the Iles and Williams Fork Formations of the Mesaverde Group, and the Lance Formation, all of Late Cretaceous age, the Fort Union Formation of Paleocene age, and locally in the Wasatch Formation of early Eocene age. The sequence of these coal-bearing rocks is shown in figure 3 from Bass et al (1955). Within the study area economic coal beds occur only in the Fort Union Formation.

The Mesaverde Group overlies and intertongues with the Upper Cretaceous Mancos Shale. The Iles Formation, in the lower part of the Mesaverde Group, consists of a sequence of rocks about 1,500 feet thick. The lower two-thirds consists of massive ledge-forming beds of sandstone interbedded with sandy shale, shale, and in its upper part, coal beds. The upper one-third of the Iles Formation consists of a shale sequence capped by a cliff-forming sandstone called the Trout Creek Sandstone.

The Williams Fork Formation includes all beds between the top of the Trout Creek Sandstone Member and the base of the Lewis Shale. Its thickness is approximately 2,000 feet in drill holes near the study area. The Williams Fork consists of a rock sequence which includes thin to massive sandstones, shale, sandy shale, and coal beds. In some areas a massive ledge-forming sandstone, the Twentymile Sandstone Member, divides the lower and upper parts of the Williams Fork Formation.

The Lewis Shale, generally about 1,000 to 2,200 feet thick, intervenes between the underlying coal-bearing Williams Fork and the overlying coal-bearing Lance Formation in the Sand Wash Basin. The marine shales of the Lewis intertongues with both the Williams Fork Formation and the Lance Formation. The Lewis is composed of soft, sandy, clay shale, containing thin beds of limestone and ferruginous concretions.

The Lance Formation, the uppermost of the Cretaceous formations in this area, consists of a typically regressive suite of sediments grading upward from nearshore marine sandstone to a succession of gray to yellow shales, thin coal beds, and massive, discontinuous crossbedded sandstones. These beds closely resemble those of the Mesaverde Group. The top of the Lance Formation is marked by a regional unconformity which separates the Cretaceous from the overlying Paleocene and Eocene rocks.



GENERALIZED COLUMNAR SECTION OF EXPOSED ROCKS
IN PARTS OF ROUTT AND MOFFAT COUNTIES, COLORADO

The coal-bearing Fort Union Formation overlies the Lance Formation. A regional unconformity is marked by a widespread basal conglomerate consisting of metamorphic and igneous pebbles from the Parks Range to the east. The conglomerate thins to the west of the study area. The Fort Union Formation consists of interbedded sandstone, shale, and coal beds, some of which are quite thick. The thickness of the Fort Union ranges from 800 to 1,100 feet thick in the study area.

The Wasatch Formation unconformably overlies the Fort Union Formation in the study area. No coal beds occur in the Wasatch Formation in the study area but to the northwest in the Hiawatha oil field area thin coal beds can be found. The Wasatch consists of medium- to coarse-grained sandstone, drab to varicolored mudstone, and some carbonaceous shale.

Coal Geology

Within the study area the Fort Union Formation contains three coal zones with economic coal beds. The lower zone contains several coal beds up to 10 feet in thickness. The middle zone contains one very thick coal bed called the Emerson bed. The Emerson bed can be correlated across the entire study area using the drill-hole data and surface measurements (figs. 1 and 4). The coal bed ranges in thickness from about 10 feet at the east end to over 25 feet to the west of the study area. The coal bed averages over 20 feet over most of the study area. The upper coal zone consists of the Blevins bed found in the upper part of the formation. The Blevins bed ranges in thickness from 6.5 feet to 15 feet but generally is over 10 feet thick in the study area. Both the Blevins and Emerson beds are strip-pable within the study area. Coals found in the Fort Union Formation are considered to be subbituminous in rank.

Coal Resources

Coal resources within the Lay Creek Study Area were calculated for the upper two coal zones. Both the Emerson and the Blevins coal beds resources have been tabulated in the demonstrated category of geologic assurance. The demonstrated category includes the subdivisions measured and indicated which are based on the nearness of the coal to a measurement of the coal bed and on the geologic evidence and projection.

Measured.--Coal for which estimates of the rank, quality, and quantity have been computed within an area whose limit is within $\frac{1}{4}$ mile (0.4 km) of a measurement in a drill hole or surface measurement.

Indicated.--Coal for which estimates of the rank, quality, and quantity have been computed within an area whose inside limit is within $\frac{1}{4}$ mile (0.4 km) from the measurement and the outside limit is $\frac{3}{4}$ mile (1.2 km) from the measurement.

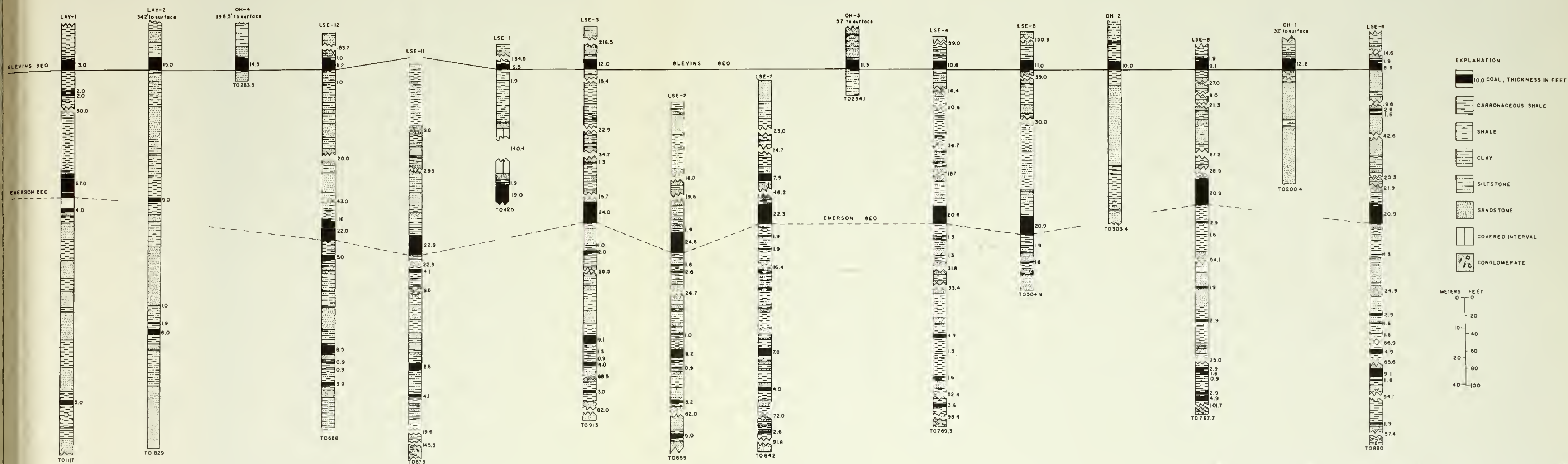


Figure 4

A summary of the demonstrated coal resources for the Emerson and Blevins coal beds found within the study area is found in the following table.

Coal resources ^{1/} Lay Creek study area	
Bed name	Demonstrated resources (tons)
<u>Area I</u>	
Blevins	19,605,119
Emerson	46,917,815
<u>Area II</u>	
Blevins	24,277,446
Emerson	50,864,332

^{1/} Resource estimates are preliminary and subject to revision.

References

- Bass, N. W., Eby, J. B., and Campbell, M. R., 1955, Geology and mineral fuels of parts of Routt and Moffat Counties, Colorado: U.S. Geol. Survey Bull. 1027-D, 250 p.
- Colson, C. T., 1969, Stratigraphy and production of the Tertiary formations in the Sand Wash and Washakie basins: Wyoming Geol. Assoc. 21st Ann. Field Conf. Guidebook, p. 121-128.
- Fenneman, N. W., 1931, Physiography of Western United States: McGraw-Hill, New York, 534 p.
- Tweto, O., 1975, Laramide (Late Cretaceous-Early Tertiary) orogeny in the southern Rocky Mountains, in Cenozoic History of the Southern Rocky Mountains: GSA Mem. 144, p. 3-17.

APPENDIX B

HYDROLOGY

Hydrology of the Lay Creek Area
of Northwestern Colorado

This appendix includes information on the ground water resources, surface water resources, and unsuitability criteria results on the Lay Creek study site.

United States Department of the Interior
Geological Survey
Water Resources Division
Denver, Colorado

Appendix B/
Hydrology^{1/}

Element	Present situation	Anticipated effect of leasing/development	Significance of anticipated impact	Data reliability	Comments
<u>Matrix for ground water resources</u>					
Type of occurrence.	Confined in Fort Union Formation; unconfined (water table) in alluvium in principal stream valleys.	Sandstone aquifers in mined area would be replaced with more permeable spoils. Alluvial aquifers probably would not be disturbed.	Would require future wells in mined areas to be about 200 feet deeper with correspondingly increased pumping lifts and power consumption.	Moderate, but adequate.	If desired, suitable wells for livestock and wildlife could be developed on tract after mining.
Quantity.	Total discharge from the site is probably less than 25 gal/min.	Inflow to pit probably insufficient for mining.	Minor supplemental water for mine use (40 to 80 acre-ft/yr) can be obtained from wells 500-1000 ft deep completed in Fort Union Formation.	Moderate, but adequate.	Discharge to adjacent valleys should increase slightly following mining.
Quality.	Dissolved-solids concentrations range from 180 to 1,400 mg/L.	Leaching of spoils would increase dissolved solids concentrations by 1,500 mg/L.	Minor, but could be long term.	Inferred from similar operations in northwestern Colorado.	Should have no effect on salinity of the Colorado River.
Importance to livestock and wildlife.	No stock-water wells or springs in proposed mine area.	None.		On-site observations.	
Importance to agriculture.	Irrigation well in Bord Gulch obtains water from alluvium subirrigation occurring along Lay Creek.	Little or none, provided that the alluvial valley floors in Bord Gulch and Lay Creek are not disturbed.	Minor, if alluvial aquifers are not mined.	Moderate. Impact largely inferred.	Bottoms of Bord Gulch and Lay Creek valley are almost certainly alluvial valley floors.
Importance to people (individual and municipal supplies).	One domestic well obtains water from alluvium in Lay Creek valley.	Little or none, if alluvial aquifers are not mined.	Minor.	Moderate.	Do.

<u>Matrix for surface water resources</u>					
Type of occurrence.	Lay Creek and all other streams are ephemeral.	Little or none.	Minor.	On-site observations.	Stream channels would be reconstructed as required by Office of Surface Mining regulations.
Quantity.	Estimated runoff is about 500 acre-ft annually.	Runoff may be reduced by as much as 100 acre-ft/yr during mining, but should return to approximately premining rates after mining.	Minor.	Poor. Effects of development largely inferred.	
Quality.	Good, probably contains less than 1,000 mg/L of dissolved solids.	Little or none.	Minor, any impacts should be short term.	Poor to moderate. Based on quality of water in reservoirs in the general area.	
Salinity of receiving waters (Colorado River).	Severe salinity problem; dissolved solids concentration downstream from Hoover Dam about 681 mg/L.	Little or no direct impact from mining. Municipal use would increase salinity of Colorado River.	Would increase salinity of Colorado River downstream from Hoover Dam by as much as 0.0107 mg/L (0.0016 percent). Impact would be long term.	Moderate. Based on inferred population increases.	Any increase in salinity of the Colorado River is a significant impact.
Importance of livestock and wildlife.	Temporary water storage provided by nine small reservoirs.	Four reservoirs would be removed by mining.	Minor, sedimentation ponds would provide alternate source of water during mining.	On-site observations.	Reservoirs could be rebuilt after mining.
Importance to agriculture.	Runoff from proposed mine area to agriculture areas in Bord Gulch and Lay Creek valleys provides less than 5 percent of surface water supply.	Loss of as much as 25 acre-ft annually in runoff to valley floors.	Minor, should be short term.	Poor. Effects of development largely inferred.	
Importance to people (individual and municipal supplies).	Runoff from proposed mine area not used for individual or municipal supplies.	None on proposed mine area. Consumptive use of Yampa River water by increased population would be about 60 to 170 acre-ft/yr.	Would reduce flow in Yampa and Colorado Rivers by corresponding amount.	Moderate. Based on inferred population increase.	Any reduction in the Colorado River is a significant impact.
Erosion and sedimentation.	Moderate erosion. Site yields an estimated 0.8 (acre-ft/mi ²)/yr.	Sedimentation ponds would reduce sediment yield from proposed mine area by 1-4 acre-ft/yr. This should offset any temporary increase in sediment yield.	Minor, long-term effect may be to slightly decrease annual sediment yield from affected areas.	On-site observation.	

Site specific summary matrix
unsuitability criteria results

Criterion	Applicable to tract	Exception used (if applicable)	Additional data needed	Comments
Alluvial valley floors.	The bottoms of Bord Gulch and Lay Creek valley on the tract are almost certainly alluvial valley floors.		Final decision on classification of alluvial valley floors and evaluation of possible impacts on the water supply by mining upstream to be made by Office of Surface Mining.	On-site observations indicate that mining in adjacent areas should have no significant impact on these valley floors provided that the alluvial aquifers are not disturbed.

^{1/} Tract name or number: LAY.

ANALYSIS OF SOILS

Project EMIRA - LAY CREEK						
Collected by	Date			Received		
Analyzed by H.F., J.S., G.H.	Date					
Location and Class DH-1						
Vegetation						
SAMPLE						
Lab No.	466	467	468	469	470	471
Field No.						
Depth, feet	42-50.6	50.6-52.5	52.5-58	70.8-84.5	84.5-110.8	110.8-115
Field texture	Shale	S.S.	Shale	Shale	S.S.	S.S.
SOIL				S.S.		
Saturation percentage	48.4	-	52.1	43.7	34.1	24.4
pH paste						
pH, 1:5 dilution	8.2	8.2	7.8	8.1	8.5	8.6
Insoluble carbonates						
Gypsum me./100 gm.						
Organic matter, percent						
SATURATION EXTRACT						
Conductivity $EC \times 10^3 @ 25^\circ C$	1.02	-	2.08	2.10	1.44	1.42
pH						
Dissolved solids p.p.m.						
Boron p.p.m.						
Carbonate me./l						
Bicarbonate me./l						
Chloride me./l	--	-	--	-	--	--
Sulfate me./l	--	-	--	-	--	--
Calcium me./l	10.10	-	24.80	24.60	15.72	14.16
Magnesium me./l						
Sodium me./l						
Potassium me./l	1.20	-	1.52	1.85	1.53	2.09
S.A.R.	.5	-	.4	.5	.5	.8
EXCHANGE RELATIONS						
Total sodium me./100 gm.	.33	-	.43	.45	.43	.43
Soluble sodium me./100 gm.	.06	-	.08	.08	.05	.05
Exchangeable sodium me./100 gm.	.27	-	.35	.37	.38	.38
Cation exchange capacity me./100 gm.	9.25	-	24.38	12.81	4.56	3.00
Exchangeable sodium percent	2.9	-	1.4	2.9	8.3	13
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05 - 2 m.m.	14.4	30.6	24.0	22.0	73.6	68.8
Percent silt .002 - .05 m.m.	57.8	51.2	33.4	48.6	5.8	3.6
Percent clay < .002 m.m.	27.8	18.2	42.6	29.4	20.6	27.6
Texture	SiCL	SiL	C	CL	SCL	SCL

ANALYSIS OF SOILS

Project EMRIA - LAY CREEK						
Collected by		Date		Received		
Analyzed by H.F., J.S., G.H.		Date 4/79				
Location and Class DH-1						
Vegetation						
SAMPLE						
Lab No.	472	473	474	475	476	477
Depth, feet	1153-	127.1-	135.2-	175.3-	185-	193.9-
Field texture	S.S.	shale	S.S.	S.S.	Conglo.	S.S.
Oil					S.S.	
Moisture percentage	33.6	46.4	37.7	33.6	34.0	35.4
Clay paste						
H, 1:5 dilution	8.6	6.1	8.3	8.5	9.1	8.7
Soluble carbonates						
Gypsum me./100 gm.						
Organic matter, percent						
SATURATION EXTRACT						
Conductivity $EC \times 10^3 @ 25^\circ C$	1.20	3.37	1.63	1.55	1.08	.99
pH						
Dissolved solids p.p.m.						
Boron p.p.m.						
Carbonate me./l						
Bicarbonate me./l						
Chloride me./l	--	.40	0	.05	.35	.35
Sulfate me./l	--	52.52	15.24	12.77	7.82	6.74
Calcium me./l	}	12.02	51.00	14.92	5.16	4.46
Magnesium me./l						
Sodium me./l		1.45	4.70	3.55	6.20	5.32
Potassium me./l						
S.A.R.	.6	.9	1.3	2.7	3.3	3.5
EXCHANGE RELATIONS						
Total sodium me./100 gm.	.43	.60	.50	.75	.65	.50
Soluble sodium me./100 gm.	.05	.22	.13	.21	.18	.18
Exchangeable sodium me./100 gm.	.38	.38	.37	.54	.47	.32
Cation exchange capacity me./100 gm.	3.75	31.63	11.56	12.00	10.44	14.13
Exchangeable sodium percent	10	1.2	3.2	4.5	4.5	2.3
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05- 2 m.m.	83.8	53.8	59.4	72.2	74.0	76.2
Percent silt .002-.05 m.m.	9.6	17.4	23.4	13.4	14.0	13.6
Percent clay < .002 m.m.	6.6	28.8	17.2	14.4	12.0	10.2
Texture	LS	SCL	SL	SL	SL	SL

ANALYSIS OF SOILS

Project	EMRIA - LAY CREEK					
Collected by	H.F., J.S., G.H.			Date	4/79	
Analyzed by				Date		
Location and Class	DH-2					

Vegetation

SAMPLE						
Lab No.	479	480	481	482	483	484
Depth, feet	27.1-		75-	129.5-	166.5-	177-
Field texture	48	58-75	129.5	146.9	177	205
SOIL	Shale	Shale	S.S.	S.S.	S.S. & Shale	Shale
Saturation percentage						
pH paste	57.2	48.6	34.6	30.5	44.2	60.5
pH, 1:5 dilution	8.3	8.3	8.4	8.6	8.3	8.4
Insoluble carbonates						
Gypsum me./100 gm.						
Organic matter, percent						
SATURATION EXTRACT						
Conductivity EC x 10 ³ @ 25°C	1.67	.99	1.28	1.02	1.05	1.45
pH						
Dissolved solids p.p.m.						
Boron p.p.m.						
Carbonate me./l						
Bicarbonate me./l						
Chloride me./l	-	.15	-	-		
Sulfate me./l	-	6.57	-	-		
Calcium me./l	}	16.76	8.82	13.26	9.66	12.00
Magnesium me./l						
Sodium me./l		2.84	1.12	1.18	1.16	4.52
Potassium me./l						
S.A.R.	1.0	.5	.5	.5	.6	1.8
EXCHANGE RELATIONS						
Total sodium me./100 gm.	.53	.45	.43	.23	.43	1.18
Soluble sodium me./100 gm.	.16	.05	.04	.04	.06	.27
Exchangeable sodium me./100 gm.	.37	.40	.39	.24	.37	.91
Cation exchange capacity me./100 gm.	17.56	11.56	5.63	3.56	11.19	47.25
Exchangeable sodium percent	2.1	3.5	6.9	6.7	3.3	1.9
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05-2 m.m.	10.0	21.0	65.0	79.0	47.2	17.8
Percent silt .002-.05 m.m.	55.0	53.4	24.4	12.6	32.6	28.2
Percent clay < .002 m.m.	35.0	25.6	10.6	8.4	20.2	84.0
Texture	SiCL	SiL	SL	LS	L	C

ANALYSIS OF SOILS

Project EMRIA - LAY CREEK						
Collected by	H.F., J.S., G.H.			Date	4/29	
Received						
Location and Class	DH-2					
Vegetation						
SAMPLE						
Lab No.	485	486	487	488	489	
Depth, feet	205-	217-	252-	264-	271-	
Field texture	S.S.-	S.S.-	S.S.	S.S.	S.S.	
SOIL	Shale	Shale				
Saturation percentage	42.6	41.9	43.2	41.1	30.7	
pH paste						
pH, 1:5 dilution	8.8	9.5	8.9	9.1	8.4	
Insoluble carbonates						
Gypsum me./100 gm.						
Organic matter, percent						
SATURATION EXTRACT						
Conductivity $EC \times 10^3 @ 25^\circ C$	1.15	1.00	1.36	1.27	1.62	
pH						
Dissolved solids p.p.m.						
Boron p.p.m.						
Carbonate me./l						
Bicarbonate me./l						
Chloride me./l						
Sulfate me./l						
Calcium me./l						
Magnesium me./l	4.20	2.20	4.60	5.10	11.10	
Sodium me./l	6.72	7.40	8.24	7.44	6.00	
Potassium me./l						
S.A.R.	4.6	7.0	5.4	4.7	2.5	
EXCHANGE RELATIONS						
Total sodium me./100 gm.	1.18	1.53	1.08	1.00	.48	
Soluble sodium me./100 gm.	.29	.31	.36	.31	.18	
Exchangeable sodium me./100 gm.	.89	1.22	.72	.69	.30	
Cation exchange capacity me./100 gm.	15.88	16.25	11.75	9.38	2.69	
Exchangeable sodium percent	5.6	7.5	6.1	7.4	11	
PARTICLE SIZE ANALYSIS						
Percent > 2m.m.						
Percent sand .05- 2m.m.	22.4	69.0	53.8	71.6	71.2	
Percent silt .002- .05m.m.	53.4	13.2	28.2	14.6	19.0	
Percent clay < .002m.m.	24.2	17.8	18.0	13.8	9.8	
Texture	SiL	SL	SL	SL	SL	

ANALYSIS OF SOILS

Project	EMRIA - LAY CREEK		
Collected by		Date	
Analized by	H.F., J.S., G.H.	Date	4/29
Location and			
Class	DH-3		

Vegetation

SAMPLE

Lab No.	491	492	493	494	495	496
	13.6-	25.1-	28.6-	38.7-	40.5-	47.4-
Depth, feet	25.1	28.6	38.7	40.5	47.4	55
Field texture	Shale	S.S.	Shale	S.S.	Shale	S.S.

SOIL

Saturation percentage	39.5	31.7	34.6	--	50.8	45.9
pH paste						
pH, 1:5 dilution	9.4	9.4	9.8	9.8	10.0	9.9
Insoluble carbonates						
Gypsum me./100 gm.						
Organic matter, percent						

SATURATION EXTRACT

Conductivity $EC \times 10^3 @ 25^\circ C$	1.44	1.89	1.46	--	1.03	1.12
pH						
Dissolved solids p.p.m.						
Boron p.p.m.						
Carbonate me./l						
Bicarbonate me./l						
Chloride me./l	2.75	.90	.35	--	.30	.50
Sulfate me./l	7.70	13.10	9.98	--	3.74	4.78
Calcium me./l	1.60	2.92	1.38	--	.78	.98
Magnesium me./l						
Sodium me./l	12.20	15.60	12.60	--	9.80	10.20
Potassium me./l						

S.A.R.	14	13	15	--	16	15
--------	----	----	----	----	----	----

EXCHANGE RELATIONS

Total sodium me./100 gm.	4.55	2.20	5.73	--	12.53	7.95
Soluble sodium me./100 gm.	.48	.49	.44	--	.50	.47
Exchangeable sodium me./100 gm.	4.07	1.71	5.29	--	12.03	7.48
Cation exchange capacity me./100 gm.	33.75	11.00	24.44	--	33.75	20.13
Exchangeable sodium percent	12	16	22	--	36	37

PARTICLE SIZE ANALYSIS

Percent > 2 m.m.						
Percent sand .05- 2 m.m.	17.4	25.2	8.8	45.6	23.2	48.0
Percent silt .002- .05 m.m.	42.4	52.4	47.4	37.6	41.2	27.4
Percent clay < .002 m.m.	40.4	22.1	43.8	16.8	35.6	24.6
Texture	SiC	SiL	SiC	L	CL	L

ANALYSIS OF SOILS

Project EMRIA - LAY CREEK

Collected by _____ Date _____ Received _____
Analyzed by H.F., J.S., G.H. Date 4/79

Location _____
and _____
Class DH-3

Vegetation _____

SAMPLE

Lab No.	497	498	499	500	501	502
Field No.						
Depth, feet	55-65	65-72	72-87	87-103	103-124	124-164
Field texture	Shale	S.S.	S.S.	S.S. & Shale	Shale	S.S.

SOIL

Saturation percentage	39.3	45.0	49.3	43.9	44.6	29.3
pH paste						
pH, 1:5 dilution	9.9	9.8	9.9	9.6	9.9	9.8
Insoluble carbonates						
Gypsum me./100 gm.						
Organic matter, percent						

SATURATION EXTRACT

Conductivity $EC \times 10^3 @ 25^\circ C$	1.44	1.63	1.86	1.96	1.43	2.74
pH						
Dissolved solids p.p.m.						
Boron p.p.m.						
Carbonate me./l						
Bicarbonate me./l						
Chloride me./l	.50	1.15	.80	.95	.75	5.40
Sulfate me./l	6.86	9.78	11.96	13.78	7.07	16.12
Calcium me./l	.94	.76	.98	1.56	1.62	2.60
Magnesium me./l						
Sodium me./l	13.20	15.60	16.75	18.00	13.20	25.50
Potassium me./l						

S.A.R.	19	25	24	20	15	22
--------	----	----	----	----	----	----

EXCHANGE RELATIONS

Total sodium me./100 gm.	8.25	4.25	9.95	4.00	9.75	2.25
Soluble sodium me./100 gm.	.52	.70	.83	.79	.59	.75
Exchangeable sodium me./100 gm.	7.73	3.55	9.12	3.21	9.16	1.50
Cation exchange capacity me./100 gm.	21.81	10.19	23.44	9.94	25.25	6.50
Exchangeable sodium percent	35	35	39	32	36	23

PARTICLE SIZE ANALYSIS

Percent > 2 m.m.						
Percent sand .05 - 2 m.m.	16.8	33.6	57.0	39.6	22.8	58.2
Percent silt .002 - .05 m.m.	45.0	47.8	25.2	39.6	42.4	24.6
Percent clay < .002 m.m.	38.2	18.6	17.8	20.8	34.8	17.2
Texture	SiCL	CL	SL	L	CL	SL

ANALYSIS OF SOILS

Project EMRIA - LAY CREEK

Collected by H.F., J.S., G.H.

Date 4/29

Received

Location and
Class DH-3

Vegetation

SAMPLE

Lab No.	503	504	505	506	507	508
Depth, feet	164-	184-	200-	211-	224-	225-
Field texture	S.S.	S.S. & Shale	S.S.	Shale	Shale	Siltstone
SOIL						
saturation percentage	26.5	60.0	25.0	--	49.0	34.0
H poste						
H, 1:5 dilution	9.1	9.5	9.1	8.8	9.5	9.7
insoluble carbonates						
gypsum me./100 gm.						
organic matter, percent						
SATURATION EXTRACT						
Conductivity EC x 10 ³ @ 25°C	1.75	1.49	1.76	--	1.17	2.10
H						
dissolved solids p.p.m.						
boron p.p.m.						
carbonate me./l						
bicarbonate me./l						
chloride me./l	.65	1.75	4.65	--	.30	.15
sulfate me./l	14.77	4.99	5.41	--	4.99	10.61
calcium me./l	7.04	.90	1.68	--	.40	.70
magnesium me./l						
sodium me./l	11.40	14.20	15.80	--	11.20	20.60
potassium me./l						
S.A.R.	6.1	21	17	--	25	35
EXCHANGE RELATIONS						
Total sodium me./100 gm.	.75	4.38	1.03	--	5.75	2.23
Soluble sodium me./100 gm.	.30	.95	.40	--	.55	.70
Exchangeable sodium me./100 gm.	.45	3.53	.63	--	5.20	1.53
Cation exchange capacity me./100 gm.	12.50	11.81	2.38	--	9.13	3.44
Exchangeable sodium percent	3.6	30	26	--	57	44
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05- 2 m.m.	81.8	20.2	67.8	14.8	11.6	24.2
Percent silt .002-.05 m.m.	11.4	51.6	22.8	29.8	49.2	50.2
Percent clay < .002 m.m.	6.8	28.2	9.4	55.4	39.2	25.6
Texture	LS	CL	SL	C	SiCL	SiL

ANALYSIS OF SOILS

Project EMRIA - LAY CREEK

Collected by _____ Date _____ Received _____
Analyzed by H.F., J.S., G.H. Date 4/79

Location
and
Access DH-4

Vegetation

SAMPLE

Sub No.	509	510	511	512	513	514
Depth, feet	13-	22.6-	36.5	47.2-	57-	66.3-
Field texture	Silt-	Shale	S.S.	Shale	S.S.	Shale
Soil	stone					
Moisture percentage	32.0	34.2	34.3	50.9	42.1	63.6
Clay paste						
H, 1:5 dilution	9.4	9.9	9.8	9.9	10.0	9.9
Soluble carbonates						
Gypsum						
me / 100 gm.						
Organic matter, percent						
SATURATION EXTRACT						
Conductivity $EC \times 10^3 @ 25^\circ C$	1.04	1.02	1.71	2.21	1.28	1.40
Dissolved solids p.p.m.						
Sulfate p.p.m.						
Carbonate me./l						
Chloride me./l						
Sulfate me./l						
Calcium me./l						
Magnesium me./l						
Sodium me./l						
Potassium me./l						
A.R.						
EXCHANGE RELATIONS						
Total sodium	me./100 gm.	2.25	6.23	3.63	14.68	5.95
Soluble sodium	me./100 gm.	.29	.33	.56	1.04	.51
Exchangeable sodium	me./100 gm.	.96	5.90	3.07	13.64	5.44
Cation exchange capacity	me./100 gm.	15.69	22.25	8.63	35.06	13.44
Exchangeable sodium percent		6.1	27	36	39	40
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05 - 2 m.m.		24.8	16.0	21.0	18.2	31.0
Percent silt .002 - .05 m.m.		47.4	45.4	49.8	36.6	44.2
Percent clay < .002 m.m.		27.8	38.6	29.2	45.2	24.8
Texture		CL	SiCL	CL	C	L

ANALYSIS OF SOILS

Project EMRIA - LAY CREEK

Collected by H.F., J.S., G.H.

Date 4/79

Received

Location
and
Class DH-4

Vegetation

SAMPLE

Lab No.	515	516	517	518	519	520
Field No.						
Depth, inches	70-74	74-82	82-85	85-93	93-95	94.6-95.5
Field texture	Silt-stone	Shale	Silt-stone	Shale	Silt-stone	Shale
SOIL						
Moisture percentage	42.5	43.4	44.6	47.7	46.5	--
Hand paste						
H, 1:5 dilution	9.9	10.0	9.9	10.0	9.8	9.9
Water-soluble carbonates						
Gypsum me./100 gm.						
Organic matter, percent						
SATURATION EXTRACT						
Conductivity $EC \times 10^3 @ 25^\circ C$	1.44	1.39	1.21	1.38	1.20	
pH						
Dissolved solids p.p.m.						
Chloride p.p.m.						
Carbonate me./l						
Bicarbonate me./l						
Chloride me./l	.25	.30	.35	.20	.45	
Sulfate me./l	6.66	7.07	4.16	7.38	6.66	
	}					
Calcium me./l						
Magnesium me./l	.80	.80	.32	.84	.68	
Sodium me./l	13.80	13.10	11.90	12.30	11.10	
Potassium me./l						
C.A.R.	22	21	30	19	19	
EXCHANGE RELATIONS						
Total sodium me./100 gm.	5.50	9.50	4.40	10.33	7.38	
Soluble sodium me./100 gm.	.59	.57	.53	.59	.52	
Exchangeable sodium me./100 gm.	4.91	8.93	3.87	9.74	6.86	
Cation exchange capacity me./100 gm.	13.44	21.25	10.31	25.00	17.81	
Exchangeable sodium percent	37	42	38	39	39	
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05 - 2 m.m.	9.2	32.6	17.4	12.0	12.0	
Percent silt .002 - .05 m.m.	61.4	33.6	52.4	39.2	57.6	
Percent clay < .002 m.m.	29.4	33.8	30.2	48.8	30.4	
Texture	SiCL	CL	SiCL	C	SiCL	

ANALYSIS OF SOILS

Project EMRIA - LAY CREEK

Collected by HF, JS, GH
Analyzed by

Date 4/79

Received

Location and Class DH-4

Vegetation

SAMPLE

Lab No.	521	522	523	524	525	526
Depth, feet	95.5-	111.3-	120.4-	192-	223-	235-
Field texture	111.3	120.4	192	223	235	236
SOIL	Silt-stone	Shale	S.S.	Shale	S.S.	Shale
Saturation percentage	46.3	52.3	53.8	64.4	28.5	--
pH paste						
pH, 1:5 dilution	9.7	9.9	9.9	9.8	9.6	9.4
Insoluble carbonates						
Gypsum me./100 gm.						
Organic matter, percent						
SATURATION EXTRACT						
Conductivity $EC \times 10^3 @ 25^\circ C$	1.50	1.64	1.53	1.70	1.97	--
pH						
Dissolved solids p.p.m.						
Boron p.p.m.						
Carbonate me./l						
Bicarbonate me./l						
Chloride me./l	.25	.25	.35	.35	.15	--
Sulfate me./l	9.15	6.86	11.86	10.61	8.74	--
Calcium me./l	.60	.88	.96	.90	.68	
Magnesium me./l						
Sodium me./l	13.80	15.80	14.20	15.40	19.60	--
Potassium me./l						
S.A.R.	25	24	21	23	34	
EXCHANGE RELATIONS						
Total sodium me./100 gm.	6.33	5.50	3.25	12.00	2.90	
Soluble sodium me./100 gm.	.64	.83	.76	.99	.56	
Exchangeable sodium me./100 gm.	5.69	4.67	2.49	11.01	2.44	
Cation exchange capacity me./100 gm.	15.94	13.75	6.31	28.75	7.19	
Exchangeable sodium percent	36	34	39	38	34	
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05-2 m.m.	11.4	11.8	71.8	15.2	33.6	
Percent silt .002-.05 m.m.	55.8	59.8	18.4	42.6	44.0	
Percent clay < .002 m.m.	32.8	28.4	9.8	42.2	22.4	
Texture	SiCL	SiCL	SL	SiC	L	

ANALYSIS OF SOILS

Project EMRIA - LAY CREEK

Collected by H.F., J.S., G.H.

Date 4/79

Received

Location
 and
 Class DH-4

Vegetation

SAMPLE

Lab No.	527	528				
Depth, feet	250.9-	251.6-				
Field texture	251.6	263.5				
	Shale	S.S.				

SOIL

Saturation percentage	--	25.9				
pH paste						
pH, 1:5 dilution	9.3	9.7				
Insoluble carbonates						
Gypsum me./100 gm.						
Organic matter, percent						

SATURATION EXTRACT

Conductivity EC x 10 ³ @ 25°C	--	2.14				
pH						
Dissolved solids p.p.m.						
Boran p.p.m.						
Carbonate me./l						
Bicarbonate me./l						
Chloride me./l	--	.35				
Sulfate me./l	--	14.14				
Calcium me./l	--	1.42				
Magnesium me./l	--	20.20				
Sodium me./l	--					
Potassium me./l						

S.A.R. 24

EXCHANGE RELATIONS

Total sodium me./100 gm.	2.98					
Saluble sodium me./100 gm.	.52					
Exchangeable sodium me./100 gm.	2.46					
Cation exchange capacity me./100 gm.	3.25					
Exchangeable sodium percent	76					

PARTICLE SIZE ANALYSIS

Percent > 2 m.m.						
Percent sand .05-2 m.m.	45.8					
Percent silt .002-.05 m.m.	41.2					
Percent clay < .002 m.m.	13.0					
Texture	L					

ANALYSIS OF SOILS

Project EMRIA - LAY CREEK

Collected by McCoy, Jibson

Date 4/22/79

Received 4/29/79

Analyzed by HF, JS, GH

Date 5/1/79

Location

and

Class

DH 1

Vegetation

SAMPLE

Lab No.	529	530	531	532		
Field No.	DH 1	DH 1	DH 1	DH 1		
Depth, inches	0-6	6-42	42-84	84-120		
Field texture	C.L.	Si.C.L.	Si.C.L.	Si.C.L.		
OIL						
Moisture percentage	38.8	48.3	45.1	46.6		
Clay paste						
Clay, 1:5 dilution						
Water-soluble carbonates	Lo	Hi	Hi	Med.		
Organic matter, percent						
SATURATION EXTRACT						
Conductivity $EC \times 10^{-3} @ 25^{\circ}C$	.270	.408	.753	2.99		
	8.0	8.2	8.9	8.4		
Dissolved solids	p.p.m.					
Calcium	p.p.m.					
Carbonate	me./l					
Non-carbonate	me./l					
Chloride	me./l					
Sulfate	me./l					
Calcium	me./l	}				
Magnesium	me./l		2.54	3.62	2.12	19.80
Sodium	me./l		.20	.81	5.84	15.80
Potassium	me./l					
S.A.R.						
	.2	.6	5.7	5.1		
EXCHANGE RELATIONS						
Total sodium	me./100 gm.	.15	.50	1.68	2.00	
Exchangeable sodium	me./100 gm.	.01	.04	.26	.74	
Exchangeable sodium	me./100 gm.	.14	.46	1.42	1.26	
Cation exchange capacity	me./100 gm.	15.06	21.25	18.44	18.75	
Exchangeable sodium percent		.9	2.2	7.7	6.7	
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05- 2 m.m.		53.4	27.8	32.6	33.4	
Percent silt .002- .05 m.m.		28.8	43.6	40.2	41.8	
Percent clay < .002 m.m.		17.8	28.6	27.2	24.8	
Texture		Sandy loam	Clay loam	Loam	Loam	

ANALYSIS OF SOILS

Project EMRIA - LAY CREEK

Collected by McCoy, Jibson

Date 4/23/79

Received 4/29/79

Analyzed by H.T., J.S., G.H.

Date 5/1/79

Location

and

Class DH-2

Vegetation

SAMPLE

Sub No.	533	534	535	536		
Field No.	DH-2	DH-2	DH-2	DH-2		
Depth, inches	0-8	8-60	60-108	108-120		
Field texture	C.L.	C.L.	Lt.C.L.	?		

SOIL G.H. Control

Moisture percentage	41.5	44.9	34.9	52.9		
1 paste						
1, 1:5 dilution						
soluble carbonates	lo	hi	hi	hi		
Gypsum me./100 gm.						
Organic matter, percent						

SATURATION EXTRACT

Conductivity $EC \times 10^3 @ 25^\circ C$	.533	.555	5.70	8.62		
	8.6	8.9	8.5	8.0		
Dissolved solids p.p.m.						
Iron p.p.m.						
Carbonate me./l						
Carbonate me./l						
Chloride me./l						
Sulfate me./l						
Calcium me./l	} 5.50	1.50	30.20	42.00		
Magnesium me./l						
Sodium me./l						
Potassium me./l	.51	4.24	40.50	48.75		

A.R.	.3	4.9	10	8.1		
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EXCHANGE RELATIONS

Total sodium me./100 gm.	.25	1.48	4.40	4.50		
Soluble sodium me./100 gm.	.02	.19	1.41	2.58		
Exchangeable sodium me./100 gm.	.23	1.29	2.99	1.92		
Cation exchange capacity me./100 gm.	18.63	17.94	18.75	17.06		
Exchangeable sodium percent	1.2	9.2	16	11		

PARTICLE SIZE ANALYSIS

Percent > 2m.m.						
Percent sand .05 - 2m.m.	48.2	35.2	36.0	Flocc.		
Percent silt .002 - .05m.m.	31.6	40.8	39.2			
Percent clay < .002m.m.	20.2	24.0	24.8			
Texture	Loam	Silt Loam	Loam			

ANALYSIS OF SOILS

Project	EMRIA - LAY CREEK		
Collected by	McCoy, Jipson	Date	4/23/79
Analyzed by	H.F., J.S., G.H.	Date	5/1/79
Location and Class	DH-3		

Vegetation

SAMPLE

Lab No.	537	538	539		
Field No.	DH3	DH3	DH3		
Depth, inches	0-24	24-60	60-120		
Field texture					

SOIL

Saturation percentage	47.4	39.9	35.2		
pH poste					
pH, 1:5 dilution					
Insoluble carbonates	Lo	Hi	lo		
Gypsum me / 100 gm.					
Organic matter, percent					

SATURATION EXTRACT

Conductivity $EC \times 10^3 @ 25^\circ C$	.347	.385	.636		
pH	8.4	8.6	8.8		
Dissolved solids p.p.m.					
Boron p.p.m.					
Carbonate me./l					
Bicarbonate me./l					
Chloride me./l					
Sulfate me./l					
Calcium me./l	}				
Magnesium me./l		3.32	2.00	1.58	
Sodium me./l		.43	2.04	4.76	
Potassium me./l					

S.A.R.	.3	2.0	5.3		
--------	----	-----	-----	--	--

EXCHANGE RELATIONS

Total sodium me./100 gm.	.33	.63	1.28		
Soluble sodium me./100 gm.	.02	.08	.17		
Exchangeable sodium me./100 gm.	.21	.55	1.11		
Cation exchange capacity me./100 gm.	23.94	13.75	19.64		
Exchangeable sodium percent	.9	4.0	5.6		

PARTICLE SIZE ANALYSIS

Percent > 2 m.m.					
Percent sand .05- 2 m.m.	34.8	33.2	31.4		
Percent silt .002- .05 m.m.	35.8	38.6	38.6		
Percent clay < .002 m.m.	29.4	28.2	30.0		
Texture	Clay Loam	Clay Loam	Clay Loam		

ANALYSIS OF SOILS

Project EMRIA - LAY CREEK						
Collected by McCoy, Jipson		Date 4/23/79		Received 4/29/79		
Analyzed by H.F., J.S., G.H.		Date 5/1/79				
Location and Class DH-4						
Vegetation						
SAMPLE						
Lob No.	540	541	542	543	544	
Field No.	DH-4	DH-4	DH-4	DH-4	DH-4	
Depth, inches	0-20	20-36	36-60	60-102	102-156	
Field texture					Shale	
SOIL						
Saturation percentage	54.1	50.4	49.1	53.5	49.2	
pH paste						
pH, 1:5 dilution						
Insoluble carbonates	hi	hi	med	med	lo	
Gypsum me./100 gm.						
Organic matter, percent						
SATURATION EXTRACT						
Conductivity EC x 10 ³ @ 25°C	.620	1.82	6.29	7.33	3.17	
pH	8.6	8.8	8.3	8.2	8.5	
Dissolved solids p.p.m.						
Boron p.p.m.						
Carbonate me./l						
Bicarbonate me./l						
Chloride me./l						
Sulfate me./l						
Calcium me./l	}	3.62	3.55	22.50	40.20	6.90
Magnesium me./l						
Sodium me./l		3.24	13.80	42.00	53.00	25.50
Potassium me./l						
S.A.R.						
	2.4	10	12	12	14	
EXCHANGE RELATIONS						
Total sodium me./100 gm.	.93	3.73	5.10	6.00	3.90	
Soluble sodium me./100 gm.	.18	.70	2.06	2.84	1.25	
Exchangeable sodium me./100 gm.	.75	3.03	3.04	3.16	2.65	
Cation exchange capacity me./100 gm.	29.88	26.31	26.25	27.94	17.00	
Exchangeable sodium percent	2.5	12	12	11	16	
PARTICLE SIZE ANALYSIS						
Percent > 2 m.m.						
Percent sand .05- 2 m.m.	27.4	23.8	26.0	27.2	22.0	
Percent silt .002- .05 m.m.	28.4	36.8	36.6	35.0	48.4	
Percent clay < .002 m.m.	44.2	39.4	37.4	37.8	29.6	
Texture	Clay	Clay Loam	Clay Loam	Clay Loam	Clay Loam	

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAY CREEK EMRIA SITE, COLORADO

LAB No	Boring Number	Depth Inch	Field Text	Hyd Cond		Set Val	pH @ 25° C		Saturation Extract				I:5 Ext		G R meq / 100 g	Co+Mg 1-5 meq / 100 g	Tension in Bars		Particle Size		
				6 Hr in/hr	24 Hr in/hr		1:5	Paste	EC _e @ 25°C, meq/l	Na meq/l	Co+Mg meq/l	SAR		Co+Mg meq/l			SAR	Sand %	Silt %	Clay %	
												True	Ext								Est
279	AH-1	0-12	SiL				8.4						.11			24.6	10.2				
280	AH-1	12-24	SiL				8.4						.12			28.4	10.9				
281	AH-1	24-36	SiL				8.9						.19			30.6	11.2				
282	AH-1	36-48	FSL				8.8		5.38	31.75	42.5	6.9	.66	2.96	2.9	24.4	8.4				
283	AH-1	48-60	SiL				8.5		8.53	50.00	95.0	7.3	1.42	12.11	2.1	26.3	9.7				
284	AH-1	60-144	SL Silt-				8.4		6.64	32.50	75.0	5.3	1.05	7.95	1.6	21.1	7.1				
285	AH-1	144-156	stone				8.5		4.88	24.75	45.0	5.2	.66	3.47	2.2	28.2	16.5				
286	AH-2	0-6	L				8.7						.11			22.4	10.1				
287	AH-2	6-24	CL				8.7						.12			31.3	13.2				
288	AH-2	24-36	CL				9.0						.21			32.5	12.6				
289	AH-2	36-72	CL				8.4		7.33	36.00	75.0	5.9	1.13	7.31	2.3	28.2	9.7				
290	AH-2	72-96	L				8.2		7.02	36.00	70.0	6.1	1.89	18.10	1.5	27.7	11.0				
291	AH-2	96-120	CL				8.3		6.47	34.50	65.0	6.1	1.22	7.80	2.5	33.3	13.4				
292	AH-2	120-132	SL				8.7		5.56	31.00	47.5	6.4	.61	1.73	4.3	34.0	12.9				
293	AH-2	132-168	SCL				9.0		5.05	29.00	37.5	6.7	.56	1.28	4.8	35.1	15.5				
294	AH-2	168-192	CL				9.2						.32								
295	AH-2	192-228	CL				9.3						.32								
296	AH-2	228-270	CL				9.2						.22								
297	AH-3	0-6	L				8.6						.07								
298	AH-3	6-24	CL				8.4						.10								
299	AH-3	24-60	CL				8.7						.15								
300	AH-3	60-96	CL				8.7						.24								
301	AH-3	96-108	CL				8.6						.40								
302	AH-4	0-12	CL				8.5						.07			25.5	8.4				
303	AH-4	12-24	CL				8.6						.12			31.6	10.9				
304	AH-4	24-60	lt. Si CL								18.0	1.2	.54	.98	6.1	28.3	10.9				

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH
LAY CREEK ENRIA SITE, COLORADO

LAB No	Boring Number	Depth Inch	Field Text.	Hyd Cond		Set Val	pH @ 25° C		Saturation Extract				I-5 Ext		G R meq / 100 g	Ca+Mg meq / 100 g	Tension in Bars			Particle Size				
				6 Hr in/hr	24 Hr in/hr		15	Poste	ECe @ 25°C meq/l	No meq/l	Ca+Mg meq/l	SAR		EC5 @ 25°C meq/l			Co+Mg meq/l	SAR Est	1/10 %	1/5 %	Moisture %	Sand %	Silt %	Clay %
												True	Ext											
305	AH-4	60-96	CL	.16	.17		8.8		10.9	76.5	87.0	11		1.16	3.60	5.7		32.3	9.1					
306	AH-4	96-114	SCL	.21	.25		8.3		12.0	85.0	98.0	11		2.51	21.89	2.7		28.7	11.2					
307	AH-4	114-136	SCL	.20	.22		8.8		8.18	57.5	55.0	11		.73	1.74	5.3		19.6	6.0					
308	AH-4	136-192	CL	.11	.10		9.2		6.97	55.5	40.0	12		.80	1.36	7.1		26.5	9.0					
309	AH-5	0-18	CL				8.7							.11										
310	AH-5	18-36	CL				8.7							.12										
311	AH-5	36-48	CL				9.0							.14										
312	AH-5	48-78	StCL				9.1							.20										
313	AH-5	78-114	StCL				9.2							.28										
314	AH-5	114-132	HCL				9.1							.35							32.6	32.2	33.2 CL	
315	AH-5	132-168	StC				8.8		4.78	22.0	43.2	4.4		.52	1.56	2.8		27.7	9.7					
316	AH-5	168-204	CL				8.8		4.98	21.25	52.5	4.2		.52	2.66	1.8		23.9	8.4					
317	AH-5	204-232	HCL				8.9							.41							42.0	30.2	27.8 CL	
318	AH-5	232-260	CL				8.8							.40										
319	AH-6	0-6	L				8.9							.17										
320	AH-6	6-36	StCL				8.8							.12										
321	AH-6	36-72	CL				8.5							.14										
322	AH-6	72-96	StC				8.7							.15										
323	AH-6	96-120	StC				8.8							.15										
324	AH-6	120-138	CL				9.0							.17										
325	AH-6	138-168	S				9.2							.10										
326	AH-6	168-186					9.0							.08										
327	AH-7	0-6	CL				8.9							.13										
328	AH-7	6-18	CL				8.8							.12										
329	AH-7	18-30	CL				8.8							.13										
330	AH-7	30-60	SCL	.1	.23		8.8		5.8	66.5	111.5			1.31	10.5	1.5	27.0	11.2						

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH
LAY CREEK EMRIA SITE COLORADO

LAB No	Boring Number	Depth Inch	Field Text.	Hyd. Cond.		Set Vol ml.	pH		Saturation Extract			I-5 Ext.		G R meq / 100 g	Co+Mg 1:5 meq / 100 g	Tension in Bars		Particle Size		Lab. Text. Class
				6 Hr. in/hr	24 Hr. in/hr		1-5 Poste. @ 25° C	Oil M CaCl2	ECe @ 25° C, meq/l	No meq/l	Co+Mg meq/l	SAR True	ECs @ 25° C, meq/l	Co+Mg meq/l	SAR Est.	1/10	15	Sand %	Silt %	Clay %
331	AH-7	60-84	SCL	.24	.26		8.9		10.4	76.0	110.0	10	1.42	9.8	2.8	19.4	6.0			
332	AH-7	84-108	LS	2.83	1.59		9.0		8.53	52.5	85.0	8.1	.76	4.8	2.4	13.8	3.8			
333	AH-8	0-6	CL				9.0						.11			30.9	14.1			
334	AH-8	6-18	C				9.0						.13			32.8	14.9			
335	AH-8	18-36	ltC				9.1						.16			33.0	13.3			
336	AH-8	36-66	CL				8.8		4.63	21.75	37.5	5.0	.56	2.4	2.6	31.2	11.7			
337	AH-9	0-12	SL				8.9						.10							
338	AH-9	12-36	SL				8.8						.13							
339	AH-9	36-48	L				8.9						.16							
340	AH-9	48-66	SL				9.1						.21							
341	AH-9	66-72	L				9.1						.25							
342	AH-9	72-78	SL				9.1						.24			19.0	5.8			
343	AH-9	78-86	LS				9.0						.27			15.2	4.2			
344	AH-9	86-120	I				8.7		7.80	26.0	79.5	3.9	.73	5.20	1.4	23.9	7.4			
345	AH-9	120-132	CL				8.6		9.71	32.0	105.0	4.4	1.04	8.4	1.2	24.9	8.3			
346	AH-9	132-180	SL				8.6		8.11	27.0	85.5	3.1	.66	5.0	1.0	16.4	5.1			
347	AH-9	180-210	SCL				8.5		8.18	19.5	100.0	2.8	1.02	8.0	1.0	24.4	8.0			
348	AH-9	210-234	CL				8.5		7.80	18.5	100.0	2.6	1.00	8.0	.9	24.1	8.7			
349	AH-9	234-276	SCL				8.5		6.04	12.5	81.25	2.0	.95	8.8	.5	20.5	6.4			
350	AH-10	0-6	CL				8.6						.16							
351	AH-10	6-24	C				9.4						.32							
352	AH-10	24-36	C	.03	.03		8.8		8.05	59.0	52.5	12	1.62	5.4	6.4	34.5	14.4			
353	AH-10	36-60	C	0	.02		8.9		6.67	59.75	40.0	13	.96	1.4	9.2	31.8	13.0			
354	AH-10	60-90	SCL	0	0		9.6		4.83	46.2	12.0	19	.51	.2	14	20.7	6.9			
355	AH-10	90-132	C	.02	.05		9.7		9.80	111.5	43.5	24	1.56	1.6	16	27.0	12.0			
356	AH-10	132-168	C	.03	.06		9.8		8.32	85.5	36.5	23	1.29	1.4	12	27.5	13.6			

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH
LAY CREEK EMERIA SITE, COLORADO

LAB No	Boring Number	Depth Inch	Field Text.	Hyd Cond.		Set, Val	pH @ 25° C		Saturation Extract				I-5 Ext		G R meq / 100 g	Co+Mg I-5 meq / 100 g	Tension in Bars		Particle Size					
				6 Hr in/hr	24 Hr in/hr		I-5 Paste	OLM CaCl2	ECe @ 25°C, meq/l	Na meq/l	Co+Mg meq/l	SAR		Co+Mg meq/l			SAR Est	1/10	15	% Moisture	Sand %	Silt %	Clay %	Lab. Text. Class
												True	Ext											
337	AH-10	168-240	HC	.05	.05		9.7		6.73	67.5	40.0	15	1.09	1.4	11			28.7	13.1					
338	AH-11	0-12	SL				9.5						.05											
339	AH-11	12-36	SL				9.0						.08											
360	AH-11	36-66	SL				9.1						.10											
361	AH-11	66-72	CL				9.5						.17											
362	AH-11	72-84	LS				9.4						.14											
363	AH-11	84-108	gravel				9.6						.13											
364	AH-11	108-120	CL	.03	.03		9.5		5.93	54.5	19.5	17	.65	.8	8.7			24.6	7.6					
365	AH-11	120-150	SiCL	.11	.13		9.4		8.46	86.5	40.0	19	1.34	1.8	11			31.1	11.4					
366	AH-11	150-180	SiC	.05	.07		9.5		8.39	85.5	36.0	20	1.40	2.0	12			31.0	12.6					
367	AH-11	180-198	SC	.05	.02		9.6		7.56	75.5	30.0	20	.79	.6	12			22.2	7.5					
368	AH-11	198-216	coarse SL				9.6						.19											
369	AH-11	216-254	LS				9.3						.09											
370	AH-11	254-288	SiC				9.2						.11											
371	AH-12	0-12	CL				8.7						.09											
372	AH-12	12-36	CL				8.8						.11											
373	AH-12	36-54	CL				9.0						.25											
374	AH-12	54-72	CL				9.1						.31											
375	AH-13	0-12	lt. CL				9.1						.09											
376	AH-13	12-36	CL				9.1						.11											
377	AH-13	36-60	CL				9.3						.09											
378	AH-14	0-6	C				9.1						.10											
379	AH-14	6-12	CL				8.9						.12											
380	AH-14	12-30	float rock CL				9.1						.11											
381	AH-14	30-54	SiC				9.3						.13											
382	AH-14	54-108	SiC				9.4						.29											

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH
LAY CREEK EMBRIA SITE, COLORADO

LAB No.	Boring Number	Depth Inch	Field Text.	Hyd Cond		Set. Vol. ml.	pH @ 25° C		Solubility Extract				EC _s @ 25° C. meq/l.	I-5 Ext		G R meq / 100 g	Co+Mg I-5 meq / 100 g	Tension in Bars		Particle Size			Lab. Text. Class
				6 Hr. 24 Hr	In/hr		1-5	Poste	EC _e @ 25° C. meq/l.	No	Co+Mg meq/l.	SAR True	Ext.	Co+Mg meq/l.	SAR Est			1/10	15	Sand %	Silt %	Clay %	
383	AH-15	0-12	L.				9.1																
384	AH-15	12-30	CL				9.0																
385	AH-15	30-54	CL				9.1																
386	AH-15	54-72	CL				9.1																
387	AH-15	72-108	lt. C				8.7																
388	AH-15	108-144	lt. C				8.6		5.16	15.0	77.0	2.4											
389	AH-16	0-6	L.				8.8																
390	AH-16	6-18	SCL				8.9																
391	AH-16	18-36	SCL				8.9																
392	AH-16	36-66	SCL				8.9																
393	AH-16	66-90	CL				9.1																
394	AH-16	90-120	CL				9.4																
395	AH-16	120-168	CL				8.8		7.50	53.5	86.0	8.2											
396	AH-16	168-192	lt. C				8.8		7.56	52.5	84.5	8.1											
418	31	0-6	lt. SIC				8.9																
419	31	6-12	C	0	.02		9.6		3.34	29.8	5.04	10						27.9	11.7				
420	31	12-24	Shale	.05	.05		8.2		9.34	93.0	35.0	16						28.6	12.9				
421	33	0-6	lt. CL				8.0																
422	33	6-18	lt. SIC				7.9																
423	33	18-42	CL				8.5																
424	33	42-60	C				9.1																
425	34	0-6	lt. CL				8.6																
426	34	6-24	CL				8.5																
427	34	24-36	CL				9.1																
428	34	36-60	lt. SCL				9.2																
429	35	0-4	lt. SIC				9.2																

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH
LAY CREEK EMRIA SITE, COLORADO

LAB No	Boring Number	Depth Inch	Field Text.	Hyd Cond		Set Vol ml.	pH @ 25° C		Saturation Extract				I:5 Ext		G R meq / 100 g	Co+Mg 1-5 meq./ 100 g	Tension in Bars		Particle Size		
				6 Hr in/hr	24 Hr in/hr.		ECe @ 25°C, meq/l	No meq/l	Co+Mg meq/l	SAR		Co+Mg meq/l	SAR Est	Sand %			Silt %	Clay %			
										15	Poste. OIM Co Cl2								True	Ext.	
383	AH-15	0-12 L					9.1						.07								
384	AH-15	12-30 CL					9.0						.09								
385	AH-15	30-54 Gr.					9.1						.12								
386	AH-15	54-72 CL					9.1						.15								
387	AH-15	72-108 lt.C					8.7						.44	3.4	.8						
388	AH-15	108-144 lt.C					8.6		5.16	15.0	77.0	2.4	.72	6.5	.6						
389	AH-16	0-6 L					8.8						.08								
390	AH-16	6-18 SCL					8.9						.09								
391	AH-16	18-36 SCL					8.9						.09								
392	AH-16	36-66 SCL					8.9						.09								
393	AH-16	66-90 CL					9.3						.11								
394	AH-16	90-120 CL					9.4						.22								
395	AH-16	120-168 CL					8.8		7.50	53.5	86.0	8.2	1.40	11.3	2.0						
396	AH-16	168-192 lt.C					8.8		7.56	52.5	84.5	8.1	1.20	8.5	2.1						
418	31	0-6 lt.Sic					8.9						.12								
419	31	6-12 C		0	.02		9.6		3.34	29.8	5.04	10	.42	.4	8.4		27.9	11.7			
420	31	12-24 Shale		.05	.05		8.2		9.34	93.0	35.0	16	2.30	12.7	5.3		28.6	12.9			
421	33	0-6 lt.CL					8.0						.07								
422	33	6-18 lt.Sic					7.9						.10								
423	33	18-42 CL					8.5						.11								
424	33	42-60 C					9.1						.18								
425	34	0-6 lt.CL					8.6						.10								
426	34	6-24 CL					8.5						.08								
427	34	24-36 CL					9.1						.12								
428	34	36-60 SCL					9.9						.21								
429	35	0-4 lt.Sic					9.2						.18								

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH

LAY CREEK ENRIA SITE, COLORADO

LAB No	Boring Number	Depth Inch	Field Text.	Hyd. Cond.		Set Vol. ml.	pH			Saturation Extract					i-5 Ext.			G.R. meq / 100 g	Co+Mg meq / 100 g	Tension in Bars			Particle Size			
				6 Hr in/hr	24 Hr in/hr		1-5	Paste	25° C	ECe @ 25°C, meq./l.	Na meq./l.	Co+Mg meq./l.	SAR		Co+Mg meq./l.	SAR	EC5 @ 25°C meq./l.			1/10 %	15 %	Moisture	Sand %	Silt %	Clay %	Lab. Text. Class
													True	Ext												
430	35	4-18	SPC			8.7										.12										
431	35	18-36	Shale			8.8			9.43	73.0	33.0	14				1.66	1.4	16								
432	36	0-8	CL			8.6										.10										
433	36	8-24	CL			8.7										.10										
434	36	24-36	SCL			8.9										.10										
435	36	36-60	Shale			9.2										.12										
436	39	0-24	ltC			8.6										.06										
437	39	24-48				8.7										.10										
438	39	48-60	lt. CL			9.2										.13										
439	40	0-24	CL			8.7										.12										
440	40	24-48	CL			.8										.13										
441	40	48-60	CL			9.0										.15										
442	42	0-14	CL			8.6										.10										
443	42	14-42	CL			8.8										.10										
444	42	42-60	SCL			8.8										.12										
445	44	0-4	CL			8.5										.10										
446	44	4-12	CL			8.4										.08										
447	44	12-24	HCL			8.4										.10										
448	44	24-36	C			9.5							Est ESP			.30							42.8	31.8	25.4	L
449	44	36-48	C	0	0	9.8			6.92	63.0	10.0	17	16	1.05	.8	15			33.9	17.2						
450	44	48-60	CL	0	0	9.3			14.8	45.0	58.0	22	30	1.74	2.0	31			28.7	12.1						
451	45	0-4	L			8.8										.14										
452	45	4-12	SL			8.9										.11										
453	45	12-24	L			8.9							Est. ESP			.13										
454	45	24-32	CL	0	.02	8.9			7.92	70.5	32.5	14	15	.89	1.2	9.5			27.0	11.2						
455	45	32-48	C	0	.02	8.8			27.6	378.0	162.0	35	34	4.5	19.0	14			29.8	16.0						

SOILS LABORATORY REPORT

BUREAU OF RECLAMATION
SALT LAKE CITY, UTAH
LAY CREEK ENRIA SITE, COLORADO

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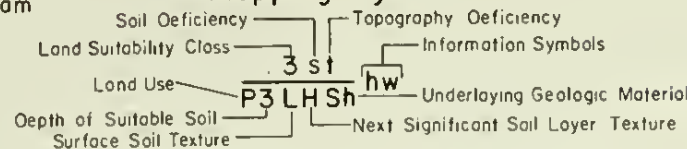
Soil Profile Symbols

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SiCL	Silty Clay Loam
SCL	Sandy Clay Loam
CL	Clay Loam
C	Clay
SiC	Silty Clay
HC	Heavy Clay
MS	Mudstone
Sh	Shale
SS	Sandstone

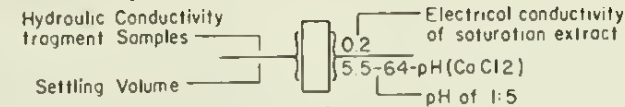
Land Use

C	Irrigated cultivated
P	Irrigated grassland
L	Nonirrigated cultivated
G	Nonirrigated grassland
B	Brush or timber
H	Suburban or homestead
I	Idle

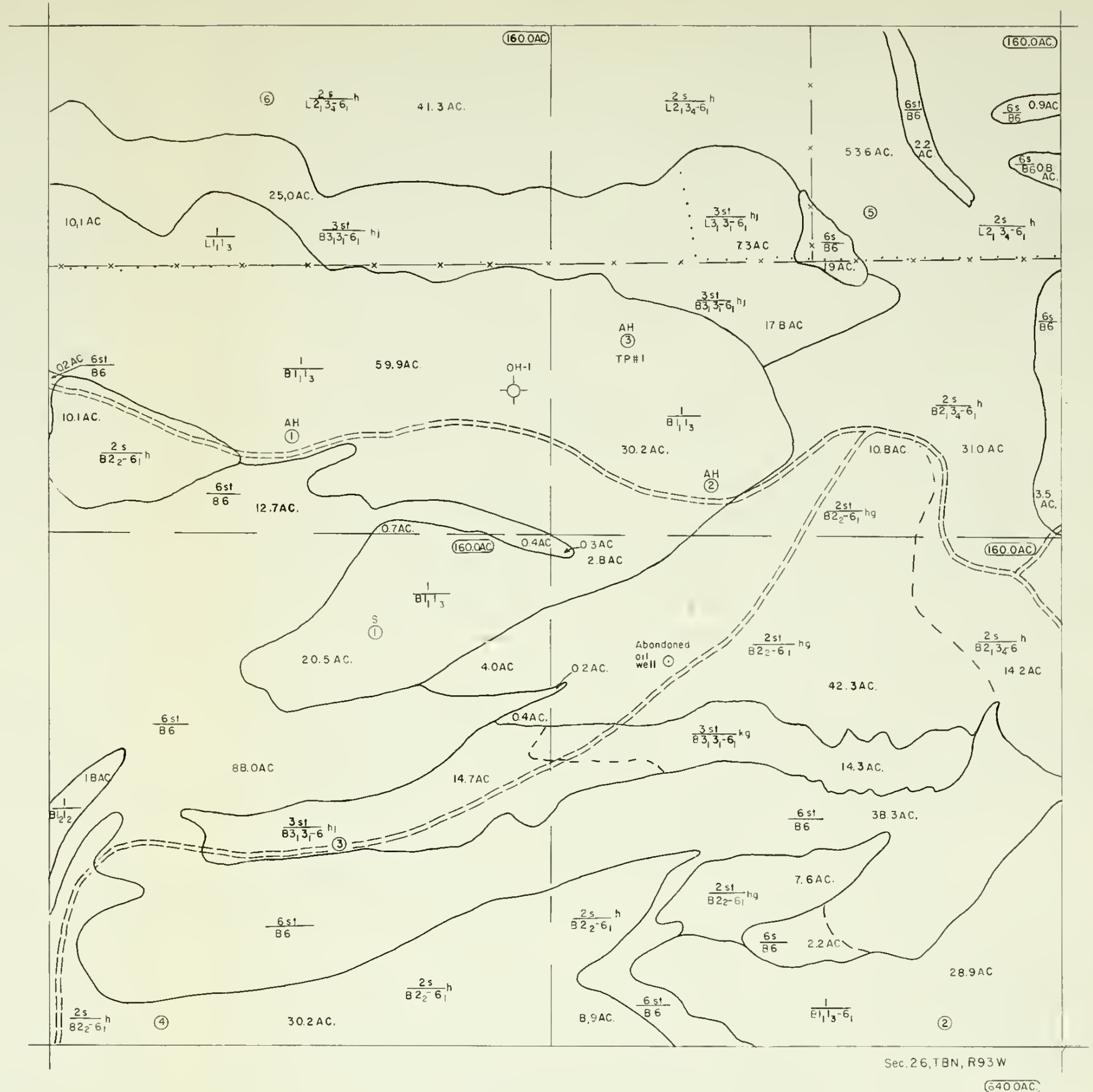
Mapping Symbol



Key to Laboratory Determination



Profile	Soil	Depth (ft)	Vegetation	Notes
I	SiC	8.5	VEG. BLACK SAGEBRUSH	
	SiC	8.7	MATCH BRUSH - NATIVE	
	C	8.0	GRASSES	
	Gr	5.32	TOPOG. 8% SLOPE (EC 5.3 BELOW 30")	
2	SiC	8.4	VEG. SAGEBRUSH	
	SiC	8.5	NATIVE GRASSES	
	Sh	8.9	TOPOG. 8% SLOPE	
	CL	3 st	TOPOG. 10% SLOPE	
3	SiC	8.4	VEG. BLACK SAGEBRUSH	
	SiC	8.5	NATIVE GRASSES	
	Sh	8.9	TOPOG. 4% SLOPE	
	CL	3 st	TOPOG. 10% SLOPE	
4	SiC	8.4	VEG. BLACK SAGEBRUSH	
	SiC	8.5	NATIVE GRASSES	
	Sh	8.9	TOPOG. 4% SLOPE	
	CL	3 st	TOPOG. 10% SLOPE	
5	SiC	8.4	VEG. SUMMER FALLOW	
	SiC	8.5	DRY FARM	
	Sh	8.9	TOPOG. 15% NORTH SLOPE	
	CL	3 st	TOPOG. 10% SLOPE	
6	SiC	8.4	VEG. WHEAT STUBBLE	
	SiC	8.5	TOPOG. 5% NORTH SLOPE	
	Sh	8.9	TOPOG. 4% SLOPE	
	CL	3 st	TOPOG. 10% SLOPE	
AH-1	SiL	8.4	VEG. BLACK SAGEBRUSH	
	SiL	8.4	NATIVE GRASSES	
	SiL	8.9	TOPOG. TOP OF NARROW RIDGE	
	SiL	8.5	TOPOG. 10% NORTH SLOPE	
AH-3	SiL	8.4	VEG. BLACK SAGEBRUSH	
	SiL	8.4	MATCH BRUSH	
	SiL	8.9	NATIVE GRASSES	
	SiL	8.5	TOPOG. 10% NORTH SLOPE	



400 0 400 800 1200
SCALE OF FEET

UNITED STATES
Department of the Interior
Bureau of Reclamation
LAY CREEK SITE EMRIA PROJECT
LAND CLASSIFICATION
Classified by B. CLARK Planimetered by J. J. J. J.
Date Sept. 1978 Photo No QUE-7JJ-81
Sec. 26 T. 8N R. 93W.
Salt Lake City, Utah

4th Section	1	2	3	Total	1	2	3	Total	Total Suitable	6	R.O.W.	Other	Grand Total
NE	30.2	95.4	25.1	150.7					150.7	9.3			160.0
NW	70.7	51.4	25.0	147.1					147.1	12.9			160.0
SW	22.3	34.6	14.7	71.6					71.6	88.4			160.0
SE	31.7	73.0	14.3	119.0					119.0	41.0			160.0
TOTAL	154.9	254.4	79.1	488.4					488.4	151.6			640.0

Sail Profile Symbols

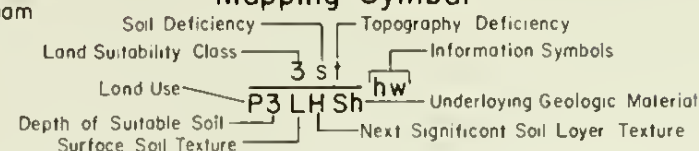
Land Use

Cb
Gr
S
LS
SL
L
SiL
SiCL
SCL
CL
C
SiC
HC
MS
Sh
SS

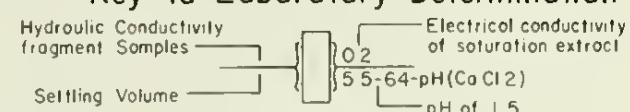
- Cobble
- Gravel
- Sand
- Loamy Sand
- Sandy Loam
- Loam
- Silt Loam
- Silty Clay Loam
- Sandy Clay Loam
- Clay Loam
- Clay
- Silty Clay
- Heavy Clay
- Mudstone
- Shale
- Sandstone

C—Irrigated cultivated
P—Irrigated grassland
L—Nonirrigated cultivated
G—Nonirrigated grassland
B—Brush or timber
H—Suburban or homestead
I—Idle

Mapping Symbol

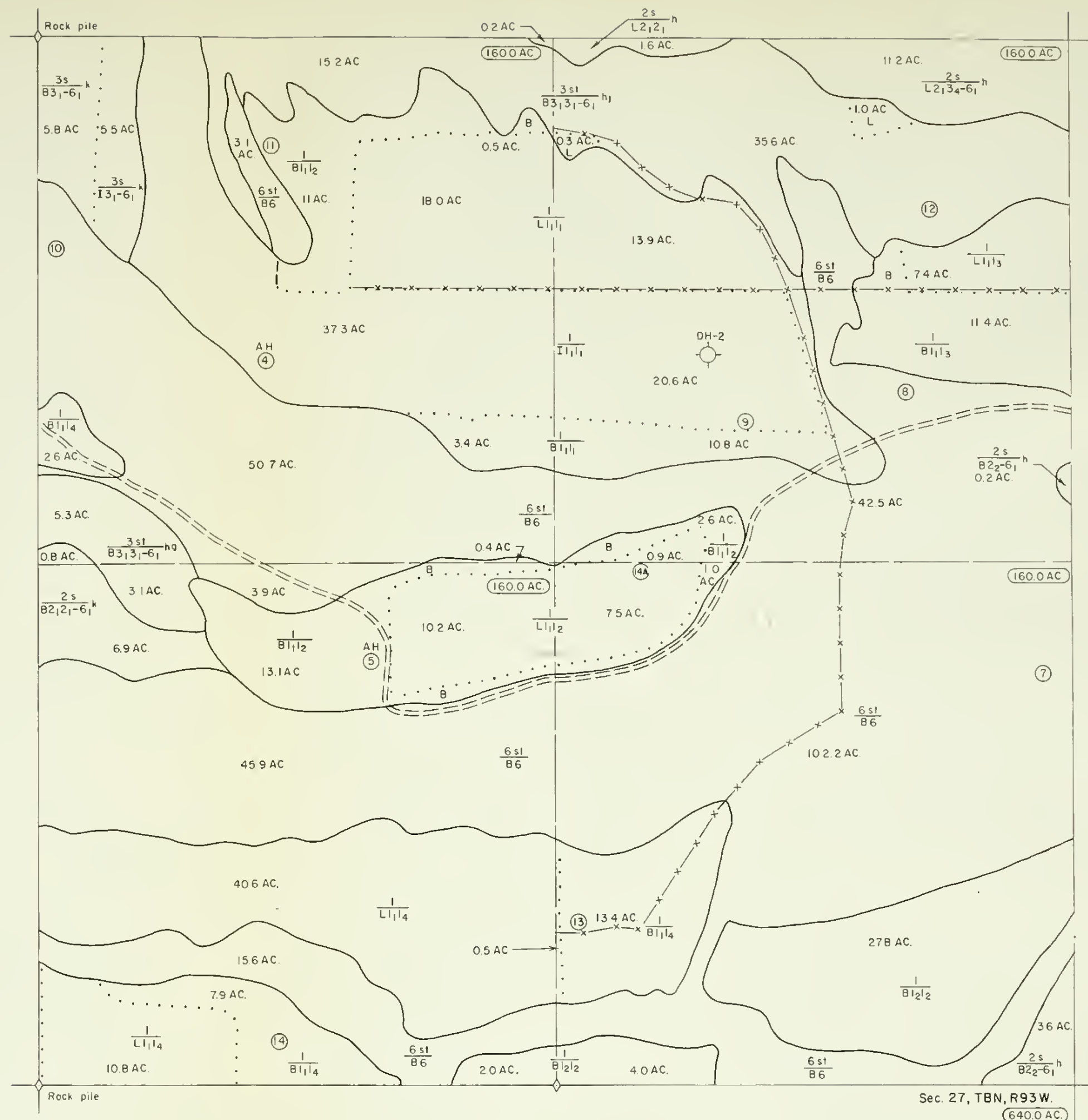


Key to Laboratory Determination



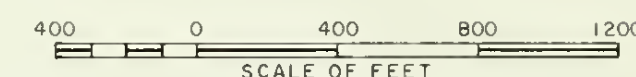
7	SL	6 st B6
SS		VEG. SAGEBRUSH AND NATIVE GRASSES TOPOG. 6 to 13% SLOPE ROUGH ROLLING RIDGES SOME SANDSTONE OUTCROPS
		6 st B6
	SL	VEG. SAGEBRUSH &
	SL S SS	JUNIPER TOPOG. 6 to 8% SLOPE ROLLING, NORTH EXPOSURE SANDSTONE OUTCROPS
9	L CL CL	8 6 8 6 9 3
IO		II I VEG. IDLE DRY FARM TOPOG. 6 to 8% SLOPE ROLLING SLOPES, LIME MYCELIA BELOW 24" - HEAVY DRY, CLODDY SOIL
		6 st B6
	L	VEG. SAGEBRUSH &
	SS	NATIVE GRASSES TOPOG. 6 to 10% SLOPE SLIGHTLY ROLLING - ROCK STREWN SURFACE
11	CL CL CL	I B1 I2 VEG. SAGEBRUSH TOPOG. HEAD OF SMALL GULLEY - SOME SANDSTONE ROCK OUTCROPS - LIME & HEAVY CLODDY SOIL
12	L CL	3 st B3 31 - 61 h VEG. SAGEBRUSH TOPOG. 8% SLOPE ROLLING
13	L CL	I B1 I4 VEG. SAGEBRUSH TOPOG. 2% SLOPE
14	CL CL	I B1 I4 VEG. SAGEBRUSH TOPOG. 5% SLOPE SLIGHTLY ROLLING
14 a	L CL CL SL	I L1 I2 VEG. DRY LAND CULTIVATED TOPOG. 3 to 5% SOUTH SLOPE

AH-4		1111	
CL	8.5	VEG. IDLE DRY FARM LAND	
CL	8.6	TOPOG. 3% SLOPE	
04	CL	452	
		93	
17	CL	10.9	
		8.8	
25	CL	12.0	
		8.3	
22	SL	8.2	
	CL	8.8	
10	SL	6.97	
	CL	9.2	
AH-5		B112	
CL	8.7	VEG. BLACK SAGEBRUSH	
CL	8.7	NATIVE GRASSES	
CL	9.0	DWARF RABBIT BRUSH	
SL	9.1	TOPOG. 3% SLOPE	
SL	9.1		
SL	9.2	MODERATE LINE 3' to 4'	
CL	9.1	HIGH LINE 4' to 6½'	
C	4.78		
	8.8		
CL	4.98		
	8.8		
CL	8.9		
CL	8.8		
CL	8.8		



Sec. 27, TBN, R93W.

(640.0 AC)



UNITED STATES
Department of the Interior
Bureau of Reclamation

LAY CREEK SITE EMRIA PROJECT
LAND CLASSIFICATION

Classified by: J.R. McCoy Planimetered by J.K. Jibson

Date Sept. 19 78 Photo No. DUE-7JJ-B1

Sec. 27 T. 8N R. 93W

Salt Lake City, Utah

4 th Section									Total Suitable	6	R.O.W	Other	Grand Total
	1	2	3	Total	1	2	3	Total					
NE	67.6	13.0	36.9	117.5					117.5	42.5			160.0
NW	73.4	1.0	31.8	106.2					106.2	53.8			160.0
SW	84.6	6.9	3.1	94.6					94.6	65.4			160.0
SE	54.2	3.6		57.8					57.8	102.2			160.0
TOTAL	279.8	24.5	71.8	376.1					376.1	263.9			640.0

Cb
Gr
S
LS
SL
L
SiL
SiCL
SCL
CL
C
SiC
HC
MS
Sh
SS

- Cobble
- Gravel
- Sand
- Loamy Sand
- Sandy Loam
- Loam
- Silt Loam
- Silty Clay Loam
- Sandy Clay Loam
- Clay Loam
- Clay
- Silty Clay
- Heavy Clay
- Mudstone
- Shale
- Sandstone

C—Irrigated cultivated
P—Irrigated grassland
L—Nonirrigated cultivated
G—Nonirrigated grassland
B—Brush or timber
H—Suburban or homestead
I—Idle

Mapping Symbol

Soil Mapping

Soil Deficiency Topography Deficiency

Land Suitability Class 3 si Information Symbols

Land Use P3 LH Sh hw Underlying Geologic Material

Depth of Suitable Soil Next Significant Soil Layer Texture

Surface Soil Texture

Key to Laboratory Determination

Hydraulic Conductivity
Fragment Samples

Settling Volume

Electrical conductivity
of saturation extract

0.2

5.5-6.4-pH (CaCl₂)

pH of 1.5

15 $\frac{2s}{8.2}$ $B2_1 2_1 - 6_1$ ^k
CL 8.2
L 8.4
S
VEG. SAGEBRUSH
TOPOG. 10 SLOPE
6" to 18" GRAVELLY

16 $\frac{6s1}{86}$
Ls
S
VEG. SAGEBRUSH
TOPOG. 25 SLOPE

17 $\frac{3s}{B3_2 3_1}$ ^k
SL
Ls
S
VEG. SAGEBRUSH
TOPOG. 4 SLOPE

18 $\frac{2s}{B2_2 2_3}$ ^h
CL
C
VEG. SAGEBRUSH
TOPOG.

19 $\frac{1}{11_2 1_2}$
CL 8.6
CL 8.7
CL 9.0
VEG. WEEDS
TOPOG. 47 SLOPE

20 $\frac{2s}{B2_2 - 6_1}$ ^k
CL
Gr
VEG. GREASEWOOD
TOPOG. 37 SLOPE

21 $\frac{1}{B1_3 1_2}$
CL
C
VEG. GRAIN STUBBLE
TOPOG. 17 SLOPE
SOIL WAS DAMP BELOW
36" MAY HAVE WATER
TABLE IN SPRING

22 $\frac{1}{B1_1 1_4 - 6_1}$
CL
CL
VEG. RUSSIAN THISTLE
TOPOG. 22 SLOPE

23 $\frac{6s1}{B6}$
CL
Gr
VEG. SPARSE SAGEBRUSH
TOPOG. 15% SLOPE

24 $\frac{2s}{B2_1 2_1 - 6_1}$ ^h
CL
C
VEG. SAGEBRUSH
TOPOG. 4% SLOPE

24-A

L

83

C

84

CL

85

C

86

C

87

C

88

C

89

C

90

S

91

0

83

0

84

0

85

0

86

0

87

0

88

0

89

0

90

0

91

25

sh

82121

VEG. SAGEBRUSH & GREASEWOOD.

TOPOG. 2% SLOPE - to EAST

MOITLINE BELOW 3'

AH-6

L

86

CL

84

CL

85

C

87

C

88

CL

90

S

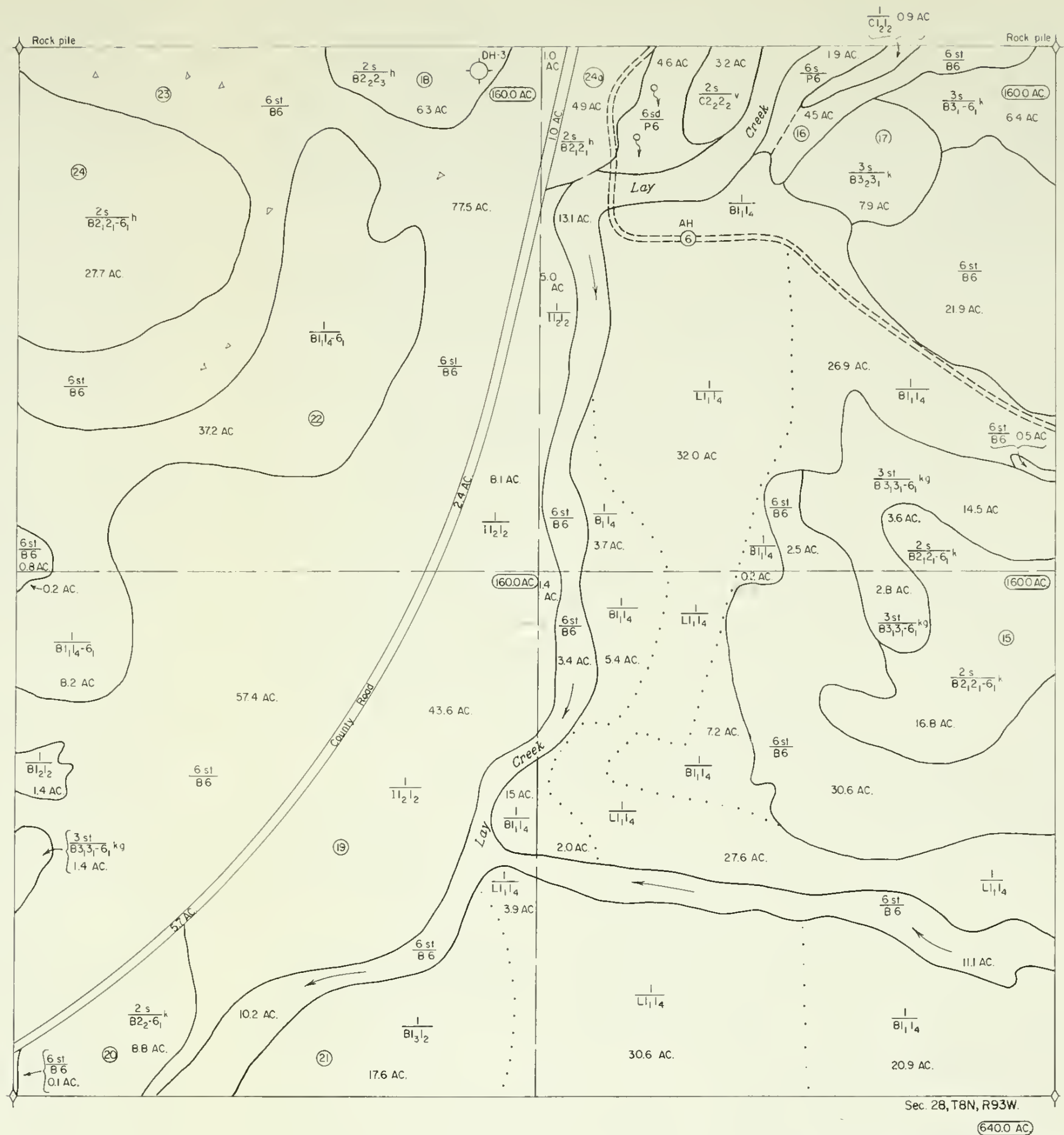
91

8114

VEG. - RABBITBRUSH - CRESTED

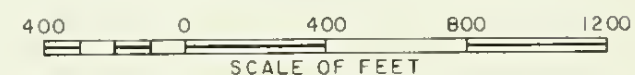
WHEATGRASS

TOPOG. 2% SLOPE



Sec. 28, T8N, R93W.

(640.0 AC)



UNITED STATES
Department of the Interior
Bureau of Reclamation

LAY CREEK SITE EMRIA PROJECT
LAND CLASSIFICATION

Classified by: P. TAYLOR Planimetered by J.K. JIBSON

Date Oct. 19 78 Photo No. DUE - 2JJ-250

Sec. 28 T. 8N R. 93W.

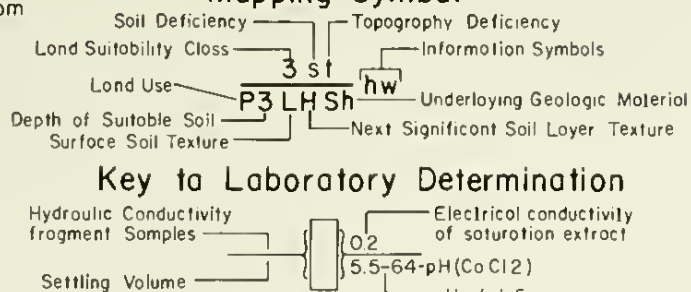
Salt Lake City, Utah

4th Section									Total Suitable	6	R.O.W	Other	Grand Total
	1	2	3	Total	1	2	3	Total					
NE	68.5	11.7	28.8	109.0					109.0	50.0	1.0		160.0
NW	45.3	34.0		79.3					79.3	78.3	2.4		160.0
SW	76.2	8.8	1.4	86.4					86.4	67.9	5.7		160.0
SE	95.3	16.8	2.8	114.9					114.9	45.1			160.0
TOTAL	285.3	71.3	33.0	389.6					389.6	241.3	9.1		640.0

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
SiCL	Silty Clay Loam
SCL	Sandy Clay Loam
CL	Clay Loam
C	Clay
SiC	Silty Clay
HC	Heavy Clay
MS	Mudstone
Sh	Shale
SS	Sandstone

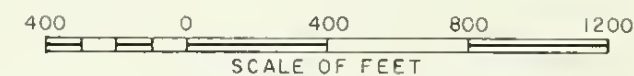
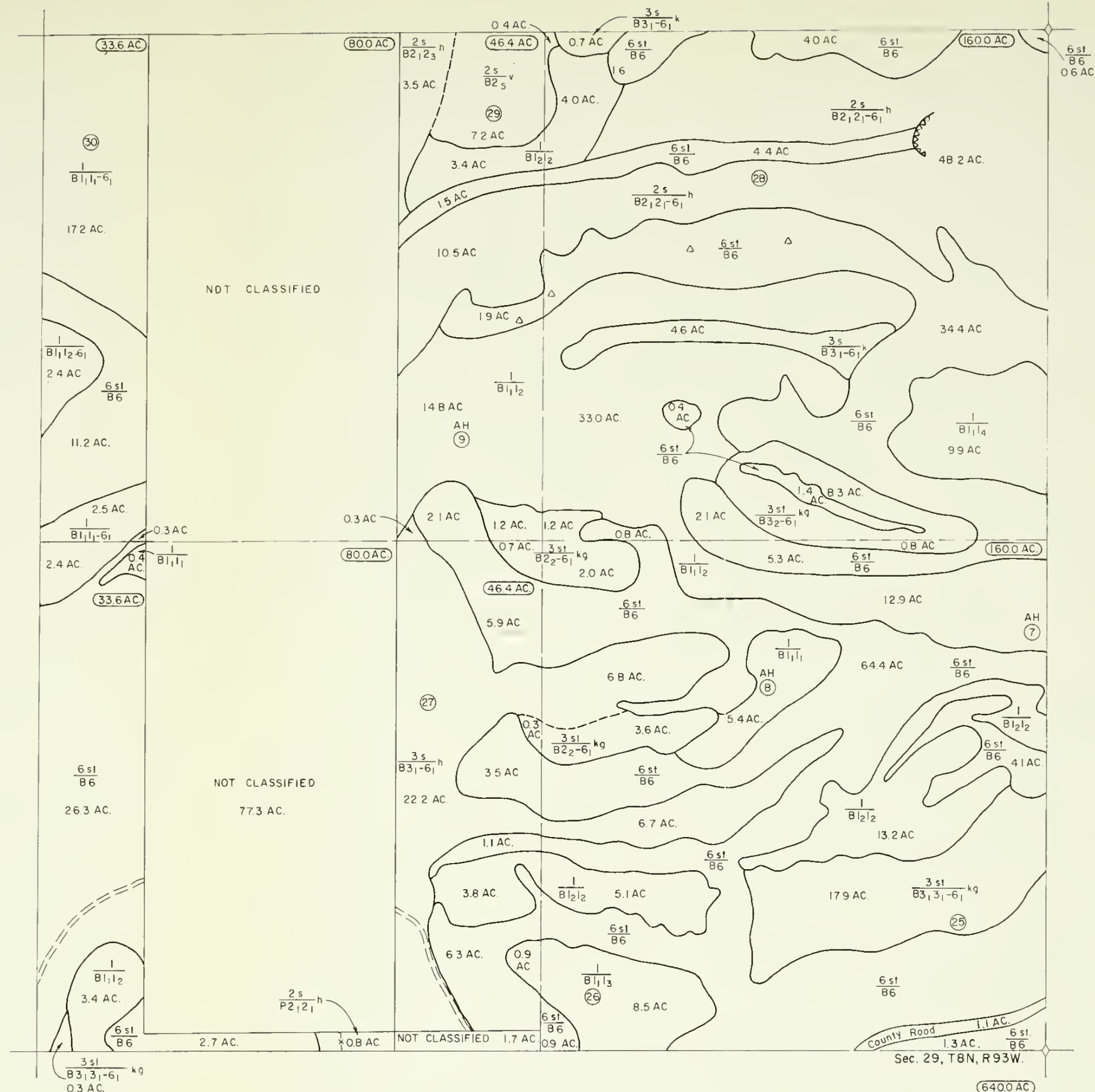
C—Irrigated cultivated
P—Irrigated grossland
L—Nonirrigated cultivated
G—Nonirrigated grossland
8—Brush or timber
H—Suburban or homestead
I—Idle

Mapping Symbol



Key to Laboratory Determination

25	CL	8.3	3s1 B3 3 -6 kg VEG. SAGEBRUSH TOPOG. 6% SLOPE
26	CL	8.3	B1 13 VEG. BLACK SAGEBRUSH TOPOG. 10% SLOPE
	CL	8.8	SANDSTONE AT 66" (EC = 5.4 at 42" to 54")
	CL	5.44 8.7	
27	CL	9.0 9.5	3s B3 -6 h VEG. GREASEBRUSH
	C	8.6 8.7	SAGEBRUSH
	CL	8.8	TOPOG. 5% SLOPE
	CL	21.2 20.5 8.6	(EC 19.7 below 18")
28	CL	8.6	2s B2 2 -6 h VEG. TALL BLACK SAGEBRUSH
	C	8.5	TOPOG. 3% SLOPE
29	SL	8.5	2s B2 5 v VEG. SPARSE SAGEBRUSH TOPOG. 3% SLOPE
30	LS	8.0	B1 1 -6 VEG. WEEDS & PASTURE
	CL	8.4	TOPOG. LOW POSITION
	L	9.5	ON SMALL CREEK FLOOD
	CL	9.8 8.9	PLAIN - MAY BE SUBJECT TO HIGH WATER TABLE
AH-7	CL	8.0	B1 12 VEG. SAGEBRUSH AND NATIVE GRASSES
	CL	8.4	TOPOG. 3% SLOPE
	CL	9.5	TO WEST - ROLLING
	CL	9.8 8.9	WEATHERED SANDSTONE 3'-9'
	CL	10.4 8.9	
	CL	8.53 9.0	
AH-8	CL	9.0	B1 1 VEG. SAGEBRUSH
	C	9.0	NATIVE GRASSES
	SL	9.1	TOPOG. 3-4% SLOPE
	CL	4.63 8.8	ROLLING
	SS		

[illegible]

UNITED STATES
Department of the Interior
Bureau of Reclamation

LAY CREEK SITE EMRIA PROJECT
LAND CLASSIFICATION

Classified by: P.R. Taylor Planimetered by JK Jibson

Date Sept 1978 Photo No. DUE-2JJ-250

Sec. 29 T. 8N R. 93W

Salt Lake City, Utah

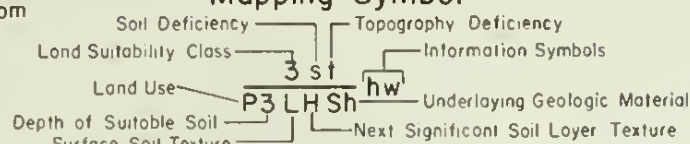
4th Section									Total Suitable	6	R.O.W	Other	Grand Total
	1	2	3	Total	1	2	3	Total					
NE	46.9	48.6	14.8	110.3					110.3	49.7			160.0
NW	40.3	21.2	1.5	63.0					63.0	17.0			80.0
SW	10.9	0.8	23.5	35.2					35.2	45.8			81.0
SE	45.1		37.8	82.9					82.9	76.0	1.1		160.0
TOTAL	143.2	70.6	77.6	291.4					291.4	188.5	1.1		481.0

Land Use

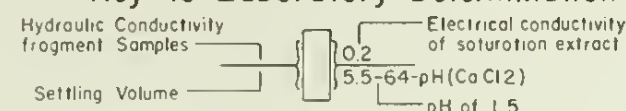
Cb	Cobble
Gr	Grovel
S	Sond
LS	Loomy Sond
SL	Sandy Loom
L	Loom
SiL	Silt Loom
SiCL	Silty Clay Loom
SCL	Sondy Clay Loom
CL	Clay Loom
C	Clay
SiC	Silty Clay
HC	Heavy Clay
MS	Mudstone
Sh	Shole
SS	Sondstone

C—Irrigated cultivated
P—Irrigated grassland
L—Nonirrigated cultivated
G—Nonirrigated grassland
B—Brush or timber
H—Suburban or homestead
I—Idle

Mapping Symbol



Key to Laboratory Determination



AH-16		B1 1-6	
S	88	VEG. SAGEBRUSH &	
	89	SMALL RABBIT BRUSH	
	89	TOPOG. 10% SLOPE	
	89		
S	CL		
	93		
S	CL		
	94		
S	CL		
	750		
S	88		
	756		
S	88		
	756		
30A		6 s	
CL	86		
	Sh	VEG. SAGEBRUSH (sparse)	
CL	Sh	TOPOG. 2% SLOPE	
	Sh		
31		6 s	
CL	86		
	Sh	VEG. NEARLY BARREN-	
CL	86	SHORT SAGEBRUSH	
	87	TOPOG. 2% SLOPE	
CL	87	ROLLING HILLS - SOME	
	87	SLOPES TO 20'	
32		6 s	
CL	86		
	Sh	VEG. SAGEBRUSH	
CL	86	TOPOG. 22% SLOPE	
	87	RAW SOIL FROM	
CL	87	SANDSTONE BELOW 6"	
	87		
33		2 s h	
CL	83	B1 1-6	
	84	VEG. SAGEBRUSH	
CL	85	TOPOG. 13% SLOPE	
	85	NORTH FACING	
CL	85		
	91		
34		B1 1-6	
CL	86	VEG. SAGEBRUSH	
	85	TOPOG. 6% SLOPE	
CL	91		
	99		
35		2 s	
CL	86		
	92	VEG. NEARLY BARREN	
CL	87	SHORT SAGEBRUSH	
	88	TOPOG. 4% SLOPE	
CL	88		
	92		
36		6 s	
CL	86		
	87	VEG. SPARSE SHORT	
CL	87	SAGEBRUSH	
	89	TOPOG. 6% SLOPE	
CL	89		
	92		

PH 07 13

37
B14

CL

VEG. SAGEBRUSH

TOPOG. 37 SLOPE

38
B112-61

CL

VEG. SAGEBRUSH

TOPOG. 10% SLOPE

39
B1212

CL

VEG. SAGEBRUSH

TOPOG. 10% SLOPE

X
B3131-61

L

VEG. SAGEBRUSH

TOPOG. 2% SLOPE

SL

BOTTOM LAND

STRATIFIED ALLUVIUM OVER

RAW SOIL FROM SHALE

Y
B6

SGr

SS

Z
B6

SL

VEG. SAGEBRUSH

TOPOG. 12% SLOPE

ROCK OUTCROPS ON RIDGES

SHALLOW TO MUDSTONE OR

SANDSTONE

SS

SS

Z1
B3131

CL

VEG. SAGEBRUSH

TOPOG. 12% SLOPE

SHORT SLOPE

RESIDUAL FROM SHALE

C

AH-10
B6

CL

VEG. SPARSE SAGEBRUSH

TOPOG. 2% SLOPE

C

SLIGHTLY ROLLING

03
B805

C

86

94

88

C

864

89

0
B83

SL

483

86

05
B80

C

97

06
B832

C

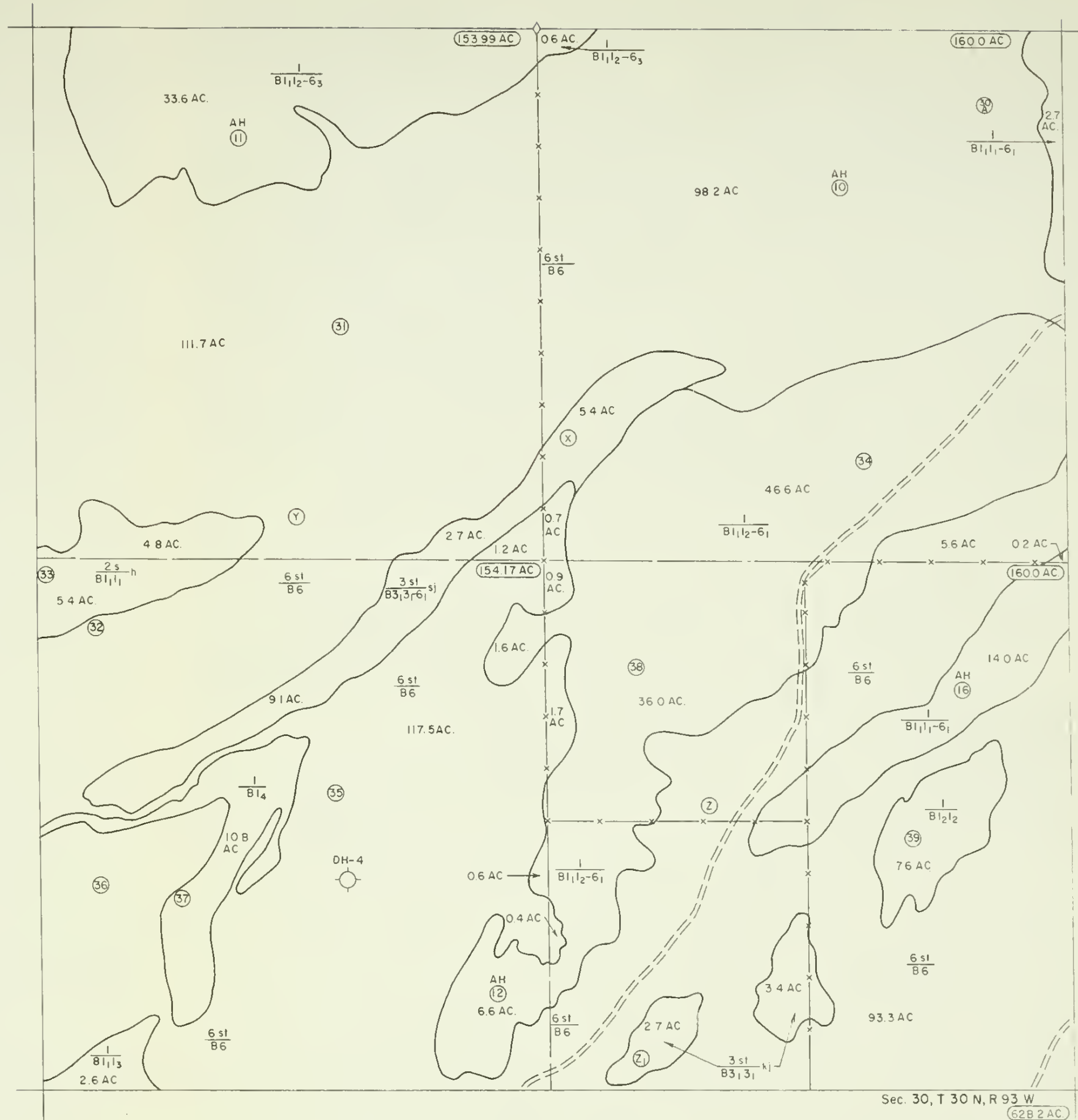
98

05
B673

Mc

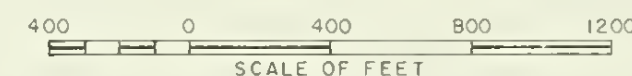
97

AH-11		B112-63	
SL	95	VEG. SAGEBRUSH	
SL	90	RABBITBRUSH	
		TOPOG. 1% SLOPE	
SL	91	UNDULATING	
CL	95		
LS	94		
GI	96		
.03	5.93		
	95		
.13	8.46		
SL	94		
.07	8.39		
	95		
.02	7.56		
SL	96		
SL	96		
SL	93		
LS	92		
Sh			
AH-12		B112-61	
CL		VEG. SAGEBRUSH	
CL		TOPOG. 7%	
CL			
L			
SS			



Sec. 30, T 30 N, R 93 W

(628 2 AC)



UNITED STATES
Department of the Interior
Bureau of Reclamation

LAY CREEK SITE EMRIA PROJECT
LAND CLASSIFICATION

Classified by P. Taylor Plonimetered by J.K. Jibson

Date Dec. 19 78 Photo No DUE-2JJ-194

Sec. 30 T. 8N R. 93W

Salt Lake City, Utah

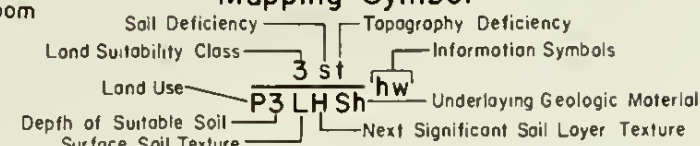
4 th Section									Total Suitable	6	R.O.W	Other	Grand Total
	1	2	3	Total	1	2	3	Total					
NE	50.1		5.4	55.5					55.5	104.5			160.0
NW	22.6	4.8	2.7	41.1					41.1	112.9			154.0
SW	22.2	5.4	9.1	36.7					36.7	117.5			154.2
SE	57.6		6.1	63.7					63.7	96.3			160.0
TOTAL	163.5	10.3	23.3	197.0					197.0	431.3			628.3

Land Use

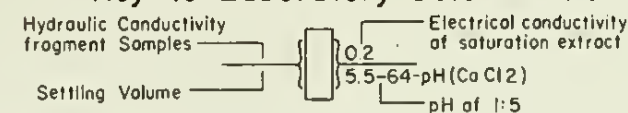
Cb	Cobble
Gr	Grovel
S	Sond
LS	Loomy Sond
SL	Sondy Loom
L	Loom
SIL	Silt Loom
SICL	Silty Cloy Loom
SCL	Sondy Cloy Loom
CL	Cloy Loom
C	Cloy
SIC	Silty Cloy
HC	Heavy Cloy
MS	Mudstone
Sh	Shole
SS	Sondstone

C - Irrigated cultivated
P - Irrigated grassland
L - Nonirrigated cultivated
G - Nonirrigated grassland
B - Brush or timber
H - Suburban or homestead
I - Idle

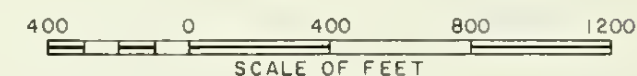
Mapping Symbol



Key to Laboratory Determination



			pH of P.S
40		81 13	
C _L	8.7	VEG. TALL SAGEBRUSH	
C _L		TOPOG. 2% SLOPE	
C _L	8.8		
C _L	9.0		
41		2 s 82 2-61 ^k	
S _L		VEG. SAGEBRUSH	
S _S		TOPOG. 8% SLOPE	
42		81 12-61	
C _L	8.6	VEG. SAGEBRUSH	
C _L		NATIVE GRASSES	
C _L	8.8	TOPOG. 1% SLOPE	
C _L	8.8	TOP OF PLATEAU	
43		2 s1 82 23-61 ^{-hg}	
C _L		VEG. SAGEBRUSH	
C _L		TOPOG. 15% SLOPE	
43o		81 11	
L		VEG. SAGEBRUSH	
C _L		TOPOG. 3% SLOPE	
C _L			
C _L			
AH-13		81 12-61	
C _L	9.1	VEG. BLACK SAGEBRUSH	
C _L		FEW NATIVE GRASSES	
C _L	9.1	SANDSTONE AT 5'	
C _L	9.8		
AH-14		3 s 83 31-66 ^k	
L	9.1	VEG. BLACK SAGEBRUSH	
S _G	8.9	NATIVE GRASSES	
S _G	9.1	TOPOG. 7% SLOPE	
S _L		ROLLING	
S _H	9.3		
Sic B			
M _S	9.4		



UNITED STATES
Department of the Interior
Bureau of Reclamation

LAY CREEK SITE EMRIA PROJECT
LAND CLASSIFICATION

Classified by: P.R. Taylor Planimetered by J.K. Jibson

Date Oct. 19 78 Photo No. DUE-2JJ-193

Sec. 31 T. 8N R. 93W

Salt Lake City, Utah

4th Section									Total Suitable	6	R.O.W	Other	Grand Total
	1	2	3	Total	1	2	3	Total					
NE	16.1	8.0	32.7	56.8					56.8	103.2			160.0
NW	49.1	23.8		72.9					72.9	81.5			154.4
SW	23.8	5.3		29.1					29.1	48.1			77.2
SE										80.0			80.0
TOTAL	89.0	37.1	32.7	158.8					158.8	312.8			471.6

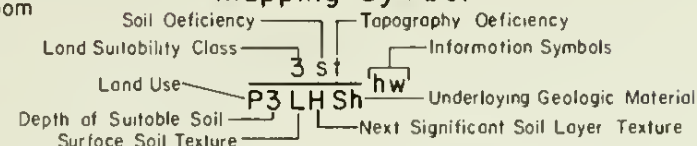
Soil Profile Symbols

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loomy Sand
SL	Sandy Loom
L	Loom
SIL	Silt Loom
SiCL	Silty Clay Loom
SCL	Sandy Clay Loom
CL	Clay Loom
C	Clay
SiC	Silty Clay
HC	Heavy Clay
MS	Mudstone
Sh	Shale
SS	Sandstone

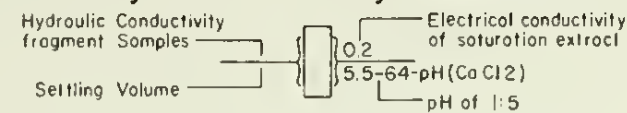
Land Use

C	Irrigated cultivated
P	Irrigated grassland
L	Nonirrigated cultivated
G	Nonirrigated grassland
B	Brush or timber
H	Suburban or homestead
I	Idle

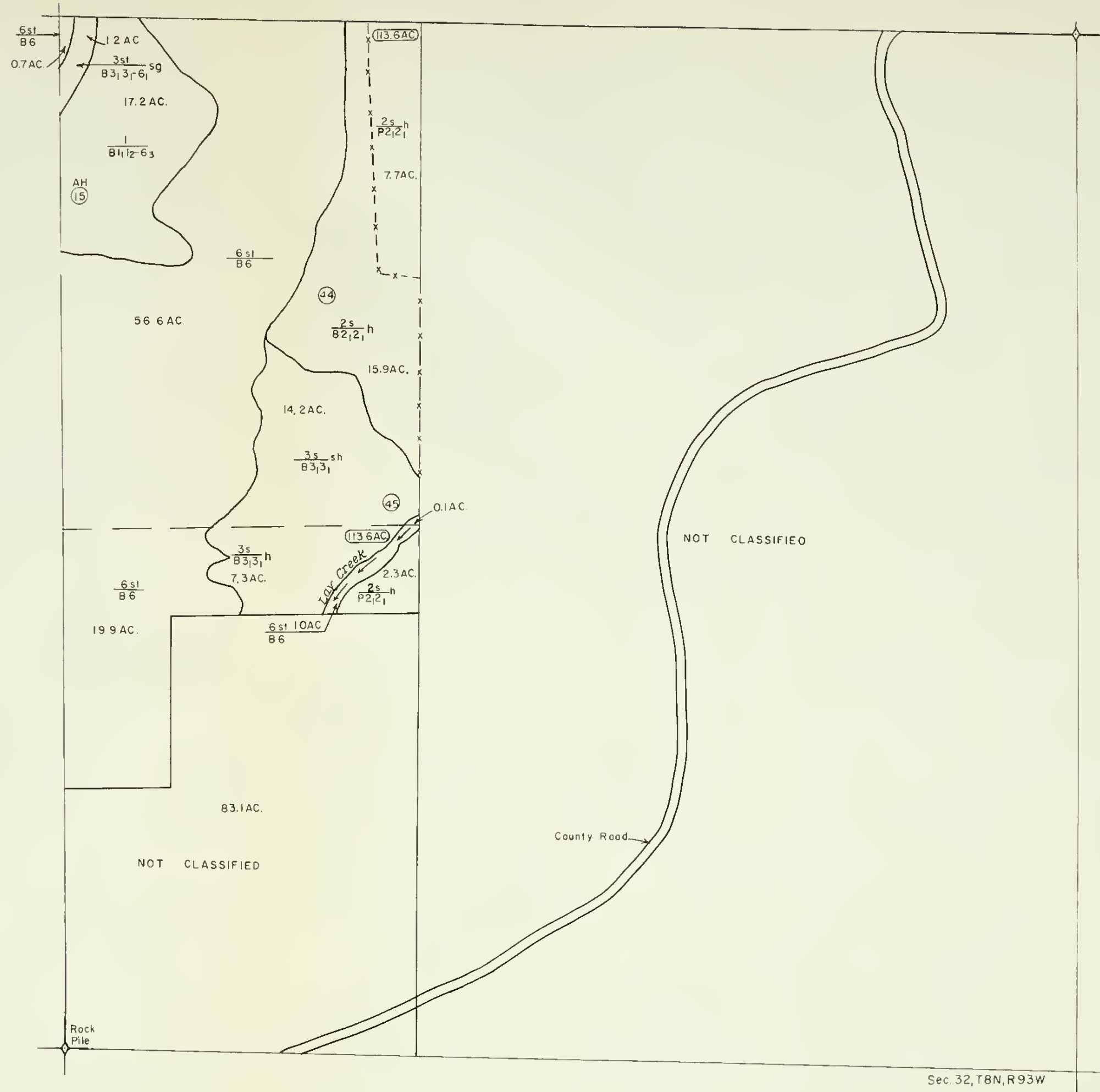
Mapping Symbol



Key to Laboratory Determination



AH-15		I			
		B1,12-63			
L	9.1	VEG. SAGEBRUSH AND			
CL	9.0	NATIVE GRASSES			
CL	9.1	TOPOG. 6% SLOPE			
CL	9.1	WEATHERED SANDSTONE			
CL	9.1	AND MUDSTONE in 9'			
C	8.7	to 12' LAYER			
C	5.16				
C	8.6				
44		2s			
		B2,2,1h			
CL	8.5	VEG. SAGEBRUSH			
CL	8.4	GREASEWOOD			
C	9.5	TOPOG. 3-6% ALLUVIAL			
C	6.32	FROM COLLUVIAL MATERIAL			
C	9.8				
C	14.8				
C	9.3				
45		3s			
		B3,3,1h			
L	8.8	VEG. GREASEWOOD			
L	8.9				
L	7.2	TOPOG. 3% SLOPE			
CL	7.2	ALLUVIAL			
C	7.9				
C	27.6	MOTTLING 48"-60" SOME			
C	6.6				
C	31.5	LINE & SLICK SPOTS			
C	9.0				



400 0 400 800 1200
SCALE OF FEET

UNITED STATES
Department of the Interior
Bureau of Reclamation

LAY CREEK SITE EMRIA PROJECT LAND CLASSIFICATION

Classified by: J.R. McCOY Planimetered by J.K. JIBSON

Date Oct 19 78 Photo No. DUE-2 JJ-251

Sec. 32 T. 8N R. 93W.

Salt Lake City, Utah

4th Section	1	2	3	Total	1	2	3	Total	Total Suitable	6	R.O.W.	Other	Grand Total
NE													
NW	17.2	23.6	15.4	56.2					56.2	57.4			113.6
SW		2.3	7.3	9.6					9.6	20.9			30.5
SE													
TOTAL	17.2	25.9	22.7	65.8					65.8	78.3			144.1

APPENDIX D

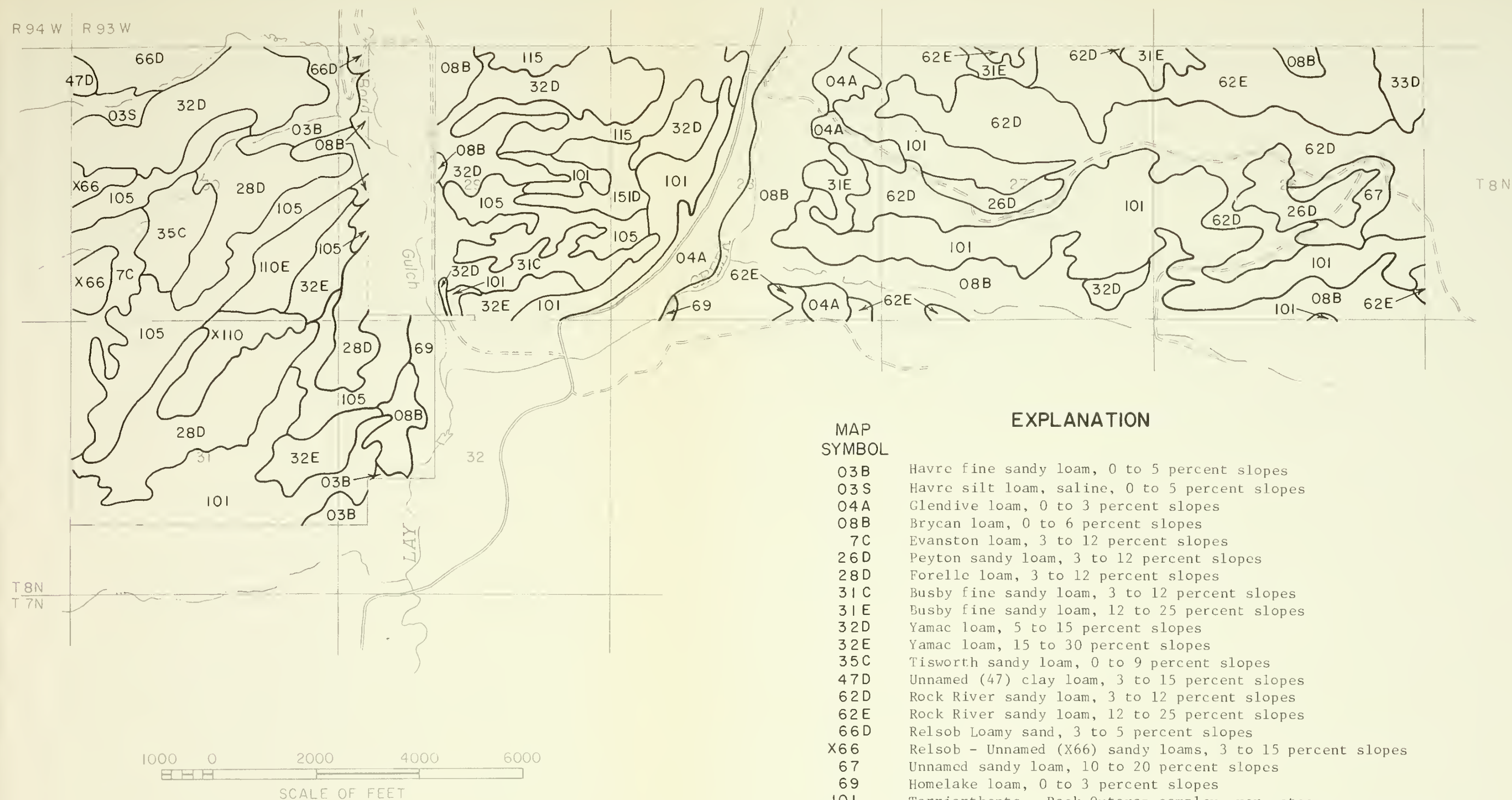
SCS SOILS DATA

Soil Survey Data Lay Creek Study Site

This appendix contains the data on the Soil Conservation Service's soil survey of the Lay Creek study site. It includes a map showing the location of the different mapping units, the taxonomy of the soil series, description of the mapping units, and descriptions of the soil series found at the study site.

United States Department of Agriculture
Soil Conservation Service
Denver, Colorado





MAP SYMBOL	EXPLANATION
03B	Havre fine sandy loam, 0 to 5 percent slopes
03S	Havre silt loam, saline, 0 to 5 percent slopes
04A	Glendive loam, 0 to 3 percent slopes
08B	Brycan loam, 0 to 6 percent slopes
7C	Evanston loam, 3 to 12 percent slopes
26D	Peyton sandy loam, 3 to 12 percent slopes
28D	Forelle loam, 3 to 12 percent slopes
31C	Busby fine sandy loam, 3 to 12 percent slopes
31E	Busby fine sandy loam, 12 to 25 percent slopes
32D	Yamac loam, 5 to 15 percent slopes
32E	Yamac loam, 15 to 30 percent slopes
35C	Tisworth sandy loam, 0 to 9 percent slopes
47D	Unnamed (47) clay loam, 3 to 15 percent slopes
62D	Rock River sandy loam, 3 to 12 percent slopes
62E	Rock River sandy loam, 12 to 25 percent slopes
66D	Relsob Loamy sand, 3 to 5 percent slopes
X66	Relsob - Unnamed (X66) sandy loams, 3 to 15 percent slopes
67	Unnamed sandy loam, 10 to 20 percent slopes
69	Homelake loam, 0 to 3 percent slopes
101	Torriorthents - Rock Outcrop complex, very steep
105	Kemmerer Moyerson silty clay loams, 20 to 40 percent slopes
X110	Kemmerer-Yamac complex, 5 to 30 percent slopes
110E	Kemmerer silty clay loam, 12 to 25 percent slopes
115	Yetull - Unnamed Lithic Ustic Torriorthent complex, steep
151D	Ryan Park loamy sand, 5 to 15 percent slopes

SCS SOIL SURVEY LAY CREEK STUDY SITE EMRIA PROJECT

APPENDIX D

SCS SOILS DATA

Taxonomy of soil series at Lay Creek study site

Series	Classification
Brycan	Fine loamy, mixed Cumulic Haploborolls
Busby	Coarse loamy, mixed Borollic Camborthids
Evanston	Fine, loamy, mixed Aridic Argiborolls
Forelle	Fine-loamy, mixed Borollic Haplargids
Glendive	Coarse-loamy, mixed (calcareous), frigid Ustic Torri- fluvents
Havre	Fine-loamy, mixed (calcareous) frigid Ustic Torri- fluvents
Homelake	Fine-loamy, mixed Fluvaquentic Haploborolls
Kemmerer	Fine, montmorillonitic Borollic Camborthids
Peyton	Fine-loamy, mixed Aridic Argiborolls
Relsob	Fine-loamy over sandy or sandy skeletal mixed Borol- lic Haplargid
Rock River	Fine-loamy, mixed Borollic Haplargids
Ryan Park	Coarse-loamy, mixed Borollic Haplargids
Tisworth	Fine-loamy, mixed Borollic Natrargids
Yamac	Fine-loamy, mixed Borollic Camborthids
Yetull	Mixed, frigid Ustic Torripsamments

SOIL SURVEY DATA
LAY CREEK STUDY SITE

03B--Havre fine sandy loam, 0 to 5 percent slopes

This is a deep, well drained soil that occurs throughout the survey area. It developed in stratified alluvium from sandstone and shale and is on flood plains and terraces at elevations of 5500 to 6800 feet. The average annual precipitation ranges from 10 to 15 inches, the average annual soil temperature is 42 to 47° F., and the frost-free season is 75 to 95 days.

Included with this soil in mapping are small areas of Homelake, Glendive, and Havre saline phase soils.

Typically, the surface layer is a dark gray fine sandy loam about 3 inches thick. The substratum is calcareous and stratified with colors of gray, light brownish gray, and pale brown. Textures are fine sandy loam, loam, sandy clay loam, silt loam, and silty clay loam. Mottling may occur below 40 inches.

Permeability is moderate. The available water capacity is high. Effective rooting depth is 60 inches or more. Surface runoff is slow, and the erosion hazard is moderate from wind and low from water.

Most of this mapping unit is used for nonirrigated and irrigated hay and pasture.

03S--Havre silt loam, saline, 0 to 5 percent slopes

This is a deep, well drained soil that occurs throughout the survey area. It developed in mixed alluvium and is on flood plains, terraces, and stream bottoms at elevations of 5500 to 7200 feet. The average annual precipitation ranges from 10 to 16 inches, the average annual soil temperature is 42 to 46° F., and the frost-free season is 75 to 105 days.

Included with this soil in mapping are a few small areas that have less than 18 percent clay in the control section, dark surface layer, or areas that have water tables at less than 60 inches below the surface.

Typically, the surface layer is a light brownish gray silt loam about 4 inches thick. The substratum is a highly stratified deposit ranging in texture from very fine sandy loam to silty clay loam and in color from dark grayish brown to pale yellow. Salt accumulations and a highly alkaline condition occur in the substratum starting at 8 to 20 inches. Some salt crusts occur on the surface especially in irrigated areas.

Permeability is slow. The available water capacity is high. Effective rooting depth is 60 inches or more. Surface runoff is slow and the erosion hazard is medium from wind and slight from water.

04A--Glendive loam, 0 to 3 percent slopes

This is a deep, well and moderately well drained soil that occurs throughout the survey area. It developed in stratified mixed alluvium and is on flood plains and terraces of streams at elevations of 5500 to 6800 feet. The average annual precipitation ranges from 10 to 15 inches, the average annual soil temperature is 42 to 47° F., and the frost-free season is 75 to 95 days.

Included with this soil in mapping are small areas of Havre, Havre saline, and Homelake soils.

Typically, the surface layer is a grayish brown fine sandy loam about 9 inches thick. The substratum is calcareous stratified materials having colors of light brown gray, gray brown, and brown having textures of fine sandy loam and loamy sand. Mottling may occur in some layers.

Permeability is moderately rapid. The available water capacity is high. Effective rooting depth is 60 inches or more. Surface runoff is slow and the erosion hazard is moderate from wind and low from water.

Most of this unit is used for nonirrigated and irrigated hay and pasture.

08B--Brycan loam, 0 to 6 percent slopes

This is a deep, well drained soil on nearly level to moderately sloping valley bottoms and stream terraces at elevations of 5800 to 7200 feet. It formed in stratified mixed alluvium. The average annual precipitation is about 12 to 14 inches, the average annual air temperature is about 40 to 45° F., and the frost-free season is 80 to 100 days.

Included in this unit are small areas of Havre, Havre saline phase, and Glendive soils.

Typically, the surface layer is dark grayish brown loam and sandy clay loam about 16 inches thick. The underlying material is grayish brown and dark grayish brown sandy clay loam extending to 41 inches over light olive brown sandy loam and loamy sand extending to 60 inches or more.

Permeability is moderate. Available water capacity is moderate. Effective rooting depth is 60 inches or more. Surface runoff is slow, and erosion hazard is moderate from wind and water.

Most of this unit is used for dryland hay or pasture. Some areas are used for livestock grazing and wildlife habitat.

7C--Evanston loam, 3 to 12 percent slopes

This is a deep, well drained soil that occurs throughout the survey area. It developed in loess and is on gently to moderately sloping

terraces at elevations of 6200 to 6500 feet. The average annual precipitation ranges from 12 to 15 inches, the average annual soil temperature is 40 to 45° F., and the frost-free season is 75 to 95 days.

Typically, the surface layer is a grayish brown loam about 8 inches thick. The subsoil is a dark brown clay loam about 12 inches thick. The upper substratum is a calcareous light brownish gray clay loam about 20 inches thick. The lower substratum is a calcareous light brownish gray loam to 60 inches or more.

Permeability is slow. The available water capacity is high. Effective rooting depth is 60 inches or more. Surface runoff is medium and the erosion hazard is moderate from wind and water.

Most of this mapping unit is cultivated and used for nonirrigated small grains.

26D--Peyton sandy loam, 3 to 12 percent slopes

This is a deep, well drained soil that occurs in the north central and central parts of the survey area. It developed in Arkosic sands and is on valley benches at elevations of 6500 to 7700 feet. The average annual precipitation ranges from 13 to 15 inches, the average annual soil temperature is 40 to 47° F., and the frost-free season is 75 to 95 days.

Included with this soil in mapping are a few small areas that have shale lenses at depths of about 30 inches or deeper, thick dark colored surface horizons, and small areas of Cruckton soils.

Typically, the surface layer is a dark grayish brown sandy loam about 8 inches thick. The subsoil is a yellowish brown coarse sandy clay loam about 10 inches thick. The upper substratum is a yellow coarse sandy loam about 24 inches thick. The lower substratum is a yellow loamy coarse sand to a depth of about 60 inches.

Permeability is moderately rapid. The available water capacity is medium. Effective rooting depth is 60 inches or more. Surface runoff is medium and the erosion hazard is high from wind and moderate from water.

Most of this mapping unit is native range and used for grazing.

28D--Forelle loam, 3 to 12 percent slopes

This is a deep, well drained soil that occurs throughout the survey area. It developed in mixed aeolian materials and is on gently to moderately sloping terraces at elevations of 6200 to 7000 feet. The average annual precipitation ranges from 12 to 15 inches, the average annual soil temperature is 42 to 47° F., and the frost-free season is 75 to 95 days.

Included with this soil in mapping are a few small areas of Yamac and Pinelli soils.

Typically, the surface layer is a grayish brown loam about 5 inches thick. The subsoil is a light brownish gray clay loam about 16 inches thick. The substratum is a light grayish brown loam to a depth of about 60 inches.

Permeability is slow. The available water capacity is high. Effective rooting depth is 60 inches or more. Surface runoff is medium and the erosion hazard is moderate from wind and water.

Most of this mapping unit is cultivated and used for nonirrigated small grains.

31C--Busby fine sandy loam, 3 to 12 percent slopes

This is a deep, well drained soil that occurs in the east part of the survey area. It developed in shale derived alluvium and is on terraces and sideslopes at elevations of 6200 to 7000 feet. The average annual precipitation ranges from 12 to 15 inches, the average annual soil temperature is 42 to 47° F., and the frost-free season is 75 to 95 days.

Typically, the surface layer is a pale brown fine sandy loam about 2 inches thick. The upper subsoil is a pale brown fine sandy loam about 4 inches thick. The lower subsoil is a brown very fine sandy loam about 6 inches thick. The substratum is a pale brown fine sandy loam.

Permeability is moderate. The available water capacity is high. Effective rooting depth is 60 inches or more. Surface runoff is slow, and the erosion hazard is moderate to high from wind and moderate from water.

Most of this mapping unit is native range and used for grazing.

31E--Busby fine sandy loam, 12 to 25 percent slopes

This is a deep, well drained soil that occurs in the southern part of the survey area. It developed in shale-derived alluvium and is on terraces and sideslopes at elevations of 6200 to 7000 feet. The average annual precipitation ranges from 12 to 15 inches, the average soil temperature is 42 to 47° F., and the frost-free season is 75 to 95 days.

Typically, the surface layer is a pale brown fine sandy loam about 2 inches thick. The upper subsoil is a pale brown fine sandy loam about 4 inches thick. The lower subsoil is a brown very fine sandy loam about 6 inches thick. The substratum is a pale brown fine sandy loam to a depth of 60 inches.

Permeability is moderate. The available water capacity is high. Effective rooting depth is 60 inches or more. Surface runoff is medium and the erosion hazard is high from wind and moderate from water.

Most of this mapping unit is native range and used for grazing.

32D--Yamac loam, 5 to 15 percent slopes

This is a deep, well drained soil that occurs in the eastern and central part of the survey area. It developed in weathered sandstone, siltstone, and windlain materials, and is on upland ridges and benches at elevations of 6200 to 7000 feet. The average annual precipitation ranges from 12 to 14 inches, the average annual soil temperature is 42 to 47° F., and the frost-free season is 75 to 95 days.

Included with this soil in mapping are a few small areas of Forelle soils.

Typically, the surface layer is a pale brown loam about 5 inches thick. The subsoil is a pale brown loam about 10 inches thick. The substratum is a pale brown to a very pale brown loam to a depth of about 60 inches.

Permeability is moderate. The available water capacity is high. Effective rooting depth is 60 inches or more. Surface runoff is medium and the erosion hazard is medium from wind and water.

Most of this mapping unit is native range and used for grazing.

32E--Yamac loam, 15 to 30 percent slopes

This is a deep, well drained soil that occurs in the eastern and central part of the survey area. It developed in weathered sandstone, siltstone, and windlain materials and is on upland sideslope and toe-slope positions at elevations of 6200 to 7000 feet. The average annual precipitation ranges from 12 to 14 inches, the average annual soil temperature is 42 to 46° F., and the frost-free season is 75 to 95 days.

Included with this soil in mapping are a few small areas that are 20 to 40 inches over sandstone and small areas of rock outcrop and somewhat lesser developed soils.

Typically, the surface layer is a pale brown loam about 5 inches thick. The subsoil is a pale brown loam about 10 inches thick. The substratum is a pale brown to a very pale brown loam to more than 60 inches.

Permeability is moderate. The available water capacity is high. Effective rooting depth is 60 inches or more. Surface runoff is medium and the erosion hazard is moderate from wind and water.

Most of this mapping unit is native range and used for grazing.

35C--Tisworth fine sandy loam, 0 to 9 percent slopes

This is a deep, well drained soil that occurs in the eastern and central parts of the survey area. It developed in alluvium or shale

residuum and is on upland benches, toeslopes, and stream terraces at elevations of 5800 to 7000 feet. The average annual precipitation ranges from 12 to 16 inches, the average annual soil temperature is 42 to 47° F., and the frost-free season is 75 to 95 days.

Included with this soil in mapping are a few small areas of Yamac and Ryan Park soils, and some small areas of soils shallow or moderately deep to shale.

Typically, the surface layer is a pale brown fine sandy loam about 3 inches thick. The subsoil is light yellowish brown light clay loam about 10 inches thick. The substratum is calcareous pale brown light clay loam extending to greater than 60 inches with scattered fine gypsum crystals.

Permeability is moderately slow. The available water capacity is high. Effective rooting depth is 60 inches or more. Surface runoff is medium and the erosion hazard is moderate from wind and high from water.

Most of this mapping unit is native range and used for grazing.

47D--Unnamed clay loam, 3 to 15 percent slopes

This is a deep, well drained soil on gently sloping to strongly sloping toeslopes and sideslopes of ridges at elevations of 6200 to 7400 feet. It formed in material weathered from shale. The average annual precipitation is about 12 to 14 inches, the average annual air temperature is about 40 to 45° F., and the frost-free season is about 80 to 100 days.

Included in this unit are small areas of Tisworth, Yamac, and Kemmerer soils.

Typically, the surface layer is brown clay loam about 4 inches thick. The subsoil is yellowish brown and pale brown clay about 17 inches thick. The substratum is light brownish gray sandy clay loam extending to 60 inches or more.

Permeability is very slow. Available water capacity is moderate. Effective rooting depth is 60 inches or more. Surface runoff is medium, and erosion hazard is low from wind and moderate from water.

Most of this unit is used for livestock grazing and wildlife habitat.

62D--Rock River loam, 3 to 12 percent slopes

This is a deep, well drained soil that occurs throughout the survey area. It developed in sandy outwash and alluvium and is on valley sideslopes and benches at elevations of 6200 to 7200 feet. The average annual precipitation ranges from 12 to 15 inches, the average annual soil temperature is 42 to 47° F., and the frost-free season is 75 to 95 days.

Included with this soil in mapping are a few small areas of Forelle and Peyton soils.

Typically, the surface layer is a yellowish brown fine sandy loam about 2 inches thick. The upper subsoil is a brown fine sandy clay loam about 3 inches thick. The lower subsoil is a dark brown fine sandy clay loam about 5 inches thick. The upper substratum is a brown calcareous fine sandy loam about 14 inches thick. The lower substratum is a light brown calcareous sandy loam to a depth of 60 inches or more.

Permeability is moderate. The available water capacity is medium. Effective rooting depth is 60 inches or more. Surface runoff is medium and the erosion hazard is moderate from wind and water.

Most of this mapping unit is native range and used for grazing.

62E--Rock River loam, 12 to 25 percent slopes

This is a deep, well drained soil that occurs throughout the survey area. It developed in sandy outwash and alluvium and is on valley side-slopes at elevations of 6200 to 7300 feet. The average annual precipitation ranges from 12 to 15 inches, the average annual soil temperature is 42 to 47° F., and the frost-free season is 75 to 95 days.

Included with this soil in mapping are a few small areas of Forelle and Peyton soils.

Typically, the surface layer is a yellowish brown fine sandy loam about 2 inches thick. The upper subsoil is a brown fine sandy clay loam about 3 inches thick. The lower subsoil is a dark brown fine sandy clay loam about 5 inches thick. The upper substratum is a brown calcareous fine sandy loam about 14 inches thick. The lower substratum is a light brown calcareous sandy loam to a depth of 60 inches or more.

Permeability is moderate. The available water capacity is medium. Effective rooting depth is 60 inches or more. Surface runoff is rapid and the erosion hazard is moderate from wind and high from water.

Most of this mapping unit is native range and used for grazing.

66D--Relsob loamy sand, 3 to 15 percent slopes

This is a deep, well drained soil on gently sloping to strongly sloping hillsides, at elevations of 6200 to 7400 feet. It formed in mixed residuum from sandstone. The average annual precipitation is about 12 to 14 inches, the average annual air temperature is about 40 to 46° F., and the frost-free season is about 80 to 100 days.

Included with this soil in mapping are a few small areas of Unnamed (67) soils, Rock River soils, and Cushool soils.

Typically, the surface layer is dark brown loamy sand about 3 inches thick. The subsoil is yellowish brown sandy clay loam about 36 inches thick. The substratum is yellow sand to 60 inches or more.

The permeability is moderate. The available water capacity is low. Effective rooting depth is 60 inches or more. Surface runoff is slow and erosion hazard is moderate from wind and slight from water.

All of this unit is used for livestock grazing and wildlife habitat.

X66--Relsob--Unnamed sandy loams, 3 to 15 percent slopes

These deep, well drained soils are on gently to strongly sloping up-land hills and ridges at elevations of 6800 to 7400 feet. They formed in residuum from sandstone and shale. Average annual precipitation is about 12 to 14 inches, the average annual air temperature is about 40 to 45° F., and the frost-free season is 75 to 95 days. Relsob soils make up 45 percent and Unnamed (X66) soils make up 25 percent of this unit. Small areas of Cushool, Unnamed (67), and Rock River soils make up the remaining 30 percent.

Typically, the Relsob soil has a surface layer that is brown sandy loam about 8 inches thick. The subsoil is yellowish brown sandy clay loam about 31 inches thick. The substratum is yellow sand to 60 inches or more.

Permeability of the Relsob soil is moderate. Effective rooting depth is 60 inches or more. Available water capacity is low. Surface runoff is slow and erosion hazard is slight from water and moderate from wind.

Typically, the Unnamed soil has a surface layer that is brown sandy loam about 6 inches thick. The subsoil is light brown sandy clay loam about 18 inches thick. The substratum is brown silty clay loam to 60 inches or more.

Permeability of the Unnamed soil is very slow. Effective rooting depth is 60 inches or more. Available water capacity is high. Surface runoff is slow and erosion hazard is slight from water and moderate from wind.

Most of this unit is native rangeland and used for livestock grazing and wildlife habitat.

67--Unnamed sandy loam, 10 to 20 percent slopes

This is a deep, excessively drained soil on strongly sloping to moderately steep slopes at elevations of 6200 to 7400 feet. It formed in material weathered from sandstone. The average annual precipitation is about 12 to 15 inches, the average annual air temperature is about 40 to 45° F., and the frost-free season is about 80 to 100 days.

Included in this unit are Relsob, Unnamed (X66), and Cushool soils. There are also areas of soil with a 6 inch sandy clay loam subsoil developed over the C horizons.

Typically, the surface layer is dark yellowish brown sandy loam about 3 inches thick. The underlying material is brownish yellow to yellow sand extending to 60 inches or more.

Permeability is moderately rapid. Available water capacity is low. Effective rooting depth is 60 inches or more. Surface runoff is slow and erosion hazard is high from wind and moderate from water.

Most of this mapping unit is used for livestock grazing and wildlife habitat.

69--Homelake loam, 0 to 3 percent slopes

This is a deep, somewhat poorly drained soil that occurs inextensively throughout the survey area. It developed in alluvium and is on floodplains of rivers and streams at elevations of 6000 to 7000 feet. The average annual precipitation ranges from 12 to 15 inches, the average annual soil temperature is 42 to 47° F., and the frost-free season is 75 to 95 days.

Typically, the surface layer is a dark grayish brown loam about 10 inches thick. The upper substratum is dark gray loam about 10 inches thick.

The middle substratum is gray very fine sandy loam about 5 inches thick. The lower substratum is gray silty clay loam to an undetermined depth. The water table is at depths below 25 inches.

Permeability is slow. The available water capacity is high. Effective rooting depth is 25 inches. Surface runoff is very slow and the erosion hazard is low from wind and low from water.

Most of this mapping unit is used for hay and pasture.

101--Torriorthents--Rock Outcrop, complex

This strongly sloping to very steep complex is on terrace and escarpment faces and valley sideslopes throughout the survey area at elevations of 6100 to 8500 feet. The average annual precipitation ranges from 8 to 16 inches, the average annual soil temperature is 42 to 47° F., and the frost-free season is 75 to 95 days. The Torriorthents make up about 50 percent of this complex and occupy small colluvial fans, toeslopes, and areas of weathered shale. The Rock Outcrop part makes up about 40 percent of this complex and occupies vertical ledges, ridgetops, and steeper sideslopes. Included with this complex in mapping are a few small areas of exposed shale ledges, with Rock River and Yamac soils in toeslope positions which make up the other 10 percent.

The Torriorthents part consists of shallow to moderately deep, coarse to medium textured, stony and cobbly, well drained soils over sandstone and shale at depths of 10 to 40 inches. These soils have light colored surface and substratum layers, and moderate to rapid permeability, low available water capacity, a moderate wind erosion hazard, and a high water erosion hazard.

The Rock Outcrop part is predominantly sandstone in long narrow bands with colluvial stones, cobbles and boulders at the base.

Most of this complex is in native range and has limited use for grazing.

105--Kemmerer--Moyerson silty clay loams, 20 to 40 percent slopes

These moderately steep and steep soils are on foothill ridge crests and sideslopes at elevations of 6000 to 6500 feet. The average annual precipitation is about 12 to 15 inches, the average annual air temperature is about 45° F. Kemmerer soil makes up about 45 percent of the mapping unit and Moyerson soil about 40 percent. Small areas of a soil similar to Kemmerer soil but not as deep, and Pinelli soils make up the other 15 percent.

Kemmerer soil is a moderately deep, well drained soil. It formed in weathered residuum from Mancos shale.

Typically, the surface layer is a light brownish gray silty clay loam about 3 inches thick. The subsoil is a light brownish gray silty clay about 15 inches thick. The substratum is a light brownish gray silty clay and overlies soft Mancos shale at a depth of 28 inches.

Permeability is slow and available water capacity is low. Surface runoff is rapid and erosion hazard is moderate.

Moyerson soil is a shallow, well drained soil. It formed in residuum in Mancos shale.

Typically, the surface layer is a light gray silty clay loam about 1 inch thick. The underlying material is a light brownish gray gravelly silty clay loam and overlies soft Mancos shale at a depth of 17 inches.

Permeability is slow and available water capacity is low. Surface runoff is rapid and erosion hazard is high.

Most of this unit is native range and used for grazing.

X110--Kemmerer--Yamac complex, 5 to 30 percent slopes

These moderately deep and deep, well drained soils are on upland shale ridges with areas of windlain deposits or sandstone remnants in the eastern part of the survey area at elevations of 6100 to 7200 feet.

The average annual precipitation ranges from 12 to 15 inches, the average annual soil temperature is 42 to 47° F., and the frost-free season is 75 to 95 days. The Kemmerer soil makes up about 60 percent of this complex and occupies ridgetops and sideslopes of ridges. The Yamac soil makes up about 20 percent of this complex and occupies ridgetop and toeslope positions. Included with this complex in mapping are a few small areas of Pinelli loam, Forelle loam, and shallow shale soils. Some small areas have sandstone outcrops, surface gravel, cobblestones, or boulders.

The Kemmerer soil is a moderately deep, well drained soil formed in shale residuum with shale at a depth of 20 to 35 inches.

Typically, the surface layer is light brownish gray silty clay loam about 3 inches thick. The subsoil is calcareous, light brownish gray clay about 12 inches thick. The substratum is light brownish gray silty clay loam about 3 inches thick that has visible gypsum seams and is over soft weathered shale at about 24 inches.

The Kemmerer soil has slow permeability and the available water capacity is low. The effective rooting depth is about 24 inches. Surface runoff is high and erosion hazard is slight from wind and moderate from water.

The Yamac soil is a deep, well drained soil forming in loess and sandstone residuum at a depth of 20 to 60 inches.

Typically, the surface layer is pale brown loam about 5 inches thick. The subsoil is a pale brown loam about 10 inches thick. The substratum is calcareous, very pale brown loam, or light clay loam.

The Yamac soil has moderate permeability and the available water capacity is high. The effective rooting depth is 60 inches or more. Surface runoff is moderately low and erosion hazard is slight from wind and moderate from water.

Most of this complex is native range and used for grazing.

110E--Kemmerer silty clay loam, 12 to 25 percent slopes

This is a moderately deep, well drained soil that occurs in the southeast part of the survey area. It developed in shale and is on upland benches, ridges, and sideslopes at elevations of 6200 to 7000 feet. The average annual precipitation ranges from 12 to 15 inches, the average annual soil temperature is 42 to 45° F., and the frost-free season is 75 to 95 days.

Included with this soil in mapping are a few small areas that have shale outcrops and surface pavement of shale chips and small areas of Moyerson and Yamac soils.

Typically, the surface layer is a light brownish gray silty clay loam about 3 inches thick. The subsoil is light brownish gray clay

about 12 inches thick; it is calcareous. The substratum is light brownish gray silty clay loam about 8 inches thick that contains visible amounts of gypsum in seams and is over soft weathered shale at about 24 inches.

Permeability is very slow. The available water capacity is low. Effective rooting depth is about 24 inches. Surface runoff is high and the erosion hazard is slight from wind and moderate from water.

Most of this mapping unit is native range and used for grazing.

115--Yetull--Lithic Torriorthents, 20 to 50 percent slopes

These moderately steep and steep soils are on foothill sideslopes and ridge crests at elevations of 6500 to 7000 feet. The average annual precipitation is about 12 to 14 inches, the average annual air temperature is about 44° F. The Yetull soil makes up about 45 percent of the mapping unit and the Lithic Torriorthents part makes up about 40 percent of the unit. About 15 percent of the unit is inclusions consisting of deep, sandy skeletal soils on sideslopes, and steep Yamac soils on leeward sideslopes below loess caps.

Yetull soil is a deep, excessively drained soil on toeslopes and sideslopes. It formed in weathered residuum from Brown's Park sandstone.

Typically, the surface layer is a light olive brown loamy sand about 3 inches thick. The lower part of the surface layer is a light olive brown loamy sand about 12 inches thick. The upper part of the underlying material is a light yellowish brown loamy sand about 25 inches thick. The lower part of the underlying material is a pale yellow sand about 7 inches thick. Hard Brown's Park sandstone is at 48 inches. The soil is calcareous throughout. In some pedons the sandstone is absent.

Permeability is rapid and the available water capacity is low. Surface runoff is medium and the erosion hazard is high from wind and low from water.

The Lithic Torriorthents part consists of shallow, excessively drained soils on ridge crests and upper sideslopes. They formed in residuum weathered from Brown's Park sandstone.

Typically, the surface layer is a light gray gravelly loamy sand about 2 inches thick. The underlying material is a light gray very gravelly loamy sand about 12 inches thick. Fractured Brown's Park sandstone is at depths of about 15 inches. The soil is calcareous throughout.

Permeability is rapid and available water capacity is low. Surface runoff is medium and the erosion hazard is high from wind and low from water.

Native vegetation consists of Indian rice grass, needleandthread, bluebunch wheatgrass, sand dropseed, Sandberg bluegrass, smooth horsebrush

big sage, and antelope bitterbrush with occasional juniper, serviceberry, and low rabbitbrush.

151--Ryan Park loamy sand, 5 to 15 percent slopes

This is a deep, somewhat excessively drained soil that formed in material weathered from sandstone. It occupies alluvial fans and hills at elevations of 6600 to 7400 feet. The average annual precipitation is 12 to 15 inches, the average annual soil temperature is 45 to 47° F., and the frost-free season is 75 to 95 days.

Included in this unit are a few small areas of Cruckton, Busby, and Rock River soils. Also included are a few small areas of Ryan Park soils which lack the surface layer due to erosion.

Typically, the surface layer is a yellowish brown loamy sand about 5 inches thick. The subsoil is a yellowish brown sandy loam about 25 inches thick. The substratum is a very pale brown sandy loam to 39 inches over a very pale brown sand to 60 inches or more. This soil is calcareous below about 23 inches.

Permeability is moderately rapid and available water holding capacity is low. Surface runoff is slow and erosion hazard is moderate from wind and slight from water.

Most of this soil is native range and used by cattle and sheep.

This soil is suited to all adapted nonirrigated crops. Yields are severely limited by the growing season, wind erosion hazard, and the droughtiness of the soil.

Seepage and wind erosion hazard are the feature of this soil most limiting to community development.

Havre Series (Ustic Torrifluvent, fine loamy mixed)

The Havre series consists of deep, well drained soils that formed in stratified alluvium from sandstone and shale. Havre soils are on flood plains and terraces and have slopes of 0 to 3 percent. The mean annual precipitation ranges from 10 to 15 inches and the mean annual soil temperature is 42 to 47° F.

Havre soils are similar to Glendive soils. Glendive soils have less than 18 percent clay in the control section.

Typical pedon of Havre fine sandy loam, 0 to 3 percent slopes, is located 1000 feet north of the center of sec. 30, T. 5 N., R. 92 W:

Al--0 to 3 inches; dark gray (10YR 4/1) fine, sandy loam, very dark grayish brown (10YR 3/2) moist; moderate medium granular structure; slightly hard, very friable, slightly sticky and slightly plastic; calcareous; mildly alkaline (pH 7.8); clear wavy boundary (3 to 7 inches thick).

C1--3 to 18 inches; light brownish gray (10YR 6/2) fine sandy loam, dark brown (10YR 3/3) moist; weak medium subangular blocky structure parting to moderate fine platy structure; slightly hard, very friable, slightly sticky and slightly plastic; calcareous; moderately alkaline (pH 8.0); clear wavy boundary (4 to 20 inches thick).

C2--18 to 29 inches; pale brown (10YR 6/3) loam, dark grayish brown (10YR 4/2) moist; weak medium subangular blocky parting to moderate fine platy structure; hard, friable, slightly sticky and slightly plastic; common fine distinct strong brown (7.5YR 5/8) and yellowish brown (10YR 5/6) mottles; calcareous; moderately alkaline (pH 8.2); gradual wavy boundary (6 to 15 inches thick).

C3--29 to 38 inches; light brownish gray (10YR 6/2) silt loam, dark grayish brown (10YR 4/2) moist; weak moderate subangular blocky parting to moderate fine platy structure; hard, friable, sticky and plastic; calcareous; moderately alkaline (pH 8.2); clear smooth boundary (8 to 15 inches thick).

Alb--38 to 53 inches; gray (10YR 5/1) silty clay loam, very dark brown (10YR 2/2) moist; moderate medium angular blocky structure; very hard, firm, sticky and plastic; calcareous; moderately alkaline (pH 8.2); clear smooth boundary (0 to 20 inches thick).

IIC1--53 to 60 inches; light brownish gray (10YR 6/2) silt loam, dark grayish brown (10YR 4/2) moist; moderate medium platy structure; very hard, friable, sticky and plastic; calcareous; moderately alkaline (pH 8.4).

The A horizon ranges in hue from 10YR through 2.5YR, in value from 4 through 6 dry, 3 through 5 moist, and in chroma from 1 through 4. The texture is commonly fine sandy loam or loam, but ranges from loamy sand to silty clay loam. The C horizons have a hue of 10YR or 2.5YR, range in value from 4 through 7 dry, 3 through 6 moist, and in chroma from 1 through 4. Textures range from loamy sand to silty clay loam, and buried horizons are common. Some thin horizons may have concentrations of sodium and gypsum.

Glendive Series (Ustic Torrifluvent, coarse loamy mixed)

The Glendive series consists of deep, well and moderately well drained soils that formed in stratified mixed alluvium. Glendive soils are on flood plains and terraces and have slopes of 0 to 3 percent. The mean annual precipitation ranges from 10 to 15 inches and the mean annual soil temperature is 42 to 47° F.

Glendive soils are similar to Havre soils. Havre soils have more than 18 percent clay in their control sections.

Typical pedon of Glendive loam, 0 to 3 percent slopes, is located 1100 feet east and 200 feet south of the NW corner of sec. 26, T. 6 N., R. 94 W.:

A11--0 to 5 inches; grayish brown (10YR 5/2) loam, dark grayish brown (10YR 4/2) moist; weak medium subangular blocky parting to moderate medium crumb structure; hard, friable, nonsticky and slightly plastic, calcareous; moderately alkaline (pH 8.4); clear smooth boundary (0 to 6 inches thick).

A12--5 to 9 inches; dark grayish brown (10YR 4/2) fine sandy loam, very dark gray (10YR 3/1) moist; weak medium subangular blocky parting to moderate medium crumb structure; slightly hard, friable, nonsticky and nonplastic; strongly alkaline (pH 8.6); clear smooth boundary (0 to 5 inches thick).

A13--9 to 14 inches; grayish brown (2.5Y 5/2) fine sandy loam, very dark grayish brown (10YR 3/2) moist; weak coarse subangular blocky parting to weak medium granular structure; slightly hard, friable, nonsticky and slightly plastic; calcareous; very strongly alkaline (pH 9.4); clear smooth boundary (0 to 8 inches thick).

C1--14 to 25 inches; light brownish gray (2.5Y 6/2) fine sandy loam, dark brown (10YR 4/3) moist; weak coarse subangular blocky parting to weak medium crumb structure; slightly hard, very friable, nonsticky and nonplastic; calcareous; strongly alkaline (pH 8.8); clear smooth boundary (5 to 22 inches thick).

C2--25 to 42 inches; light brownish gray (2.5Y 6/2) loamy sand, dark brown (10YR 4/3) moist; weak very coarse subangular blocky structure parting to single grains; soft, very friable, nonsticky and nonplastic; calcareous; strongly alkaline (pH 8.8); clear smooth boundary (15 to 30 inches thick).

C3--42 to 55 inches; grayish brown (2.5Y 5/2) fine sandy loam, dark grayish brown (10YR 4/2) moist; weak very coarse subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; common medium prominent strong brown (7.5YR 5/6) mottles; carbonates in fine seams and streaks; calcareous; strongly alkaline (pH 8.8); clear smooth boundary (8 to 30 inches thick).

C4--55 to 60 inches; brown (10YR 5/3) loamy sand, dark yellowish brown (10YR 4/4) moist; massive structure; slightly hard, loose, nonsticky and nonplastic; calcareous; moderately alkaline (pH 8.2).

The A horizon hue is 10YR or 2.5Y, in value 4 through 6 dry, 3 through 5 moist, and in chroma from 1 through 4. Textures range from loamy sand to loam. The C horizons range in hue from 10YR through 2.5Y, in value from 1 through 4. Textures range from sands and gravels to loams and sandy clay loams.

08--Brycan Series (Cumulic Haploboroll, fine loamy, mixed)

The Brycan series consists of deep, well drained soils that formed in mixed alluvium. Brycan soils are on valley bottoms and stream terraces and have slopes of 0 to 6 percent. The average annual precipitation is about 12 to 14 inches, the average annual air temperature is about 40 to

to 45° F., and the frost-free season is 80 to 100 days. Elevations are 5800 to 7200 feet.

The Brycan soils are similar to the Homelake soils. They are near the Havre, Glendive, and Homelake soils. Homelake soils are somewhat poorly drained. Havre and Glendive soils have light colored surface horizons, and Glendive soils have less than 18 percent clay in the control section.

Typical pedon of Brycan loam, 0 to 6 percent slopes, is about 6 miles north of Lay, 200 feet north and 100 feet west of the southeast corner of sec. 32, T. 8 N., R. 93 W.:

A11--0 to 5 inches; dark grayish brown (10YR 4/2) loam, very dark grayish brown (10YR 3/2) moist; moderate very coarse platy parting to moderate medium subangular blocky structure; slightly hard, very friable, slightly sticky and slightly plastic; neutral, gradual wavy boundary.

A12--5 to 16 inches; grayish brown (2.5Y 5/2) sandy clay loam, very dark grayish brown (2.5Y 3/2) moist; moderate coarse subangular blocky parting to moderate medium subangular blocky structure, slightly hard, friable, sticky and plastic; neutral; clear wavy boundary.

C1--16 to 20 inches; grayish brown (2.5Y 5/2) sandy clay loam, very dark grayish brown (2.5Y 3/2) moist; moderate very coarse platy parting to moderate medium subangular blocky structure; hard, friable, sticky and plastic; calcareous; mildly alkaline; clear wavy boundary.

C1--20 to 27 inches; dark grayish brown (10YR 4/2) sandy clay loam, very dark grayish brown (2.5Y 3/2) moist; moderate coarse subangular blocky structure; hard friable, sticky and plastic; calcareous; mildly alkaline; clear wavy boundary.

C3ca--27 to 41 inches; grayish brown (2.5Y 5/2) sandy clay loam, dark grayish brown (2.5Y 4/2) moist; moderate coarse subangular blocky structure; hard, friable, sticky and plastic; calcareous; mildly alkaline; visible lime in seams and streaks; clear wavy boundary.

C4--41 to 54 inches; light olive brown (2.5Y 5/4) sandy loam, dark grayish brown (2.5Y 4/2) moist; weak medium subangular blocky structure; soft, very friable, nonsticky and nonplastic; calcareous; mildly alkaline; gradual wavy boundary.

C5--54 to 60 inches; light yellowish brown (2.5Y 6/4) loamy sand, grayish brown (2.5Y 5/2) moist; single grain; loose; calcareous; mildly alkaline.

Thickness of the mollic epipedon ranges from 16 to 27 inches. Depth to calcareous material ranges from 20 to greater than 40 inches. Buried A and B horizons are common. Sand and gravel layers may occur, but rock fragments throughout the control section are generally less than 15 percent.

A horizon has hue of 10YR through 2.5Y, value of 3 through 5 dry, 2 through 4 moist, and chroma of 1 through 3. C horizons have hue of 10YR through 2.5Y, value of 3 through 6 dry, 2 through 5 moist, and chroma of 2 through 4. Textures of the C horizons range from loamy sand to clay loam. Reaction is neutral to mildly alkaline.

Evanston Series (Ardic Argiborollos, fine loamy mixed)

The Evanston series consists of deep, well drained soils that formed in mixed alluvium and loess. Evanston soils are on gently sloping to steep uplands. Slopes are 3 to 25 percent. The mean annual precipitation ranges from 12 to 15 inches and the mean annual soil temperature is 42 to 47° F.

Evanston soils are similar to Attewan, Forelle, Peyton, and Work series. Attewan soils have a sandy skeletal substrata above a depth of 40 inches. Forelle soils lack a mollic epipedon. Peyton soils are noncalcareous to depths of at least 40 inches. Work soils have greater than 35 percent clay in the control section.

Typical pedon of Evanston loam, 3 to 12 percent slope is located in sec. 31, T. 7 N., R. 90 W.:

Ap--0 to 8 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; soft, very friable, slightly sticky and slightly plastic; many roots; mildly alkaline (pH 7.4); clear smooth boundary (6 to 10 inches thick).

B2t--8 to 16 inches; grayish brown (10YR 5/2) clay loam very dark grayish brown (10YR 3/2) moist; moderate, medium prismatic structure that parts to moderate medium subangular blocky; slightly hard, friable, sticky and plastic; continuous moderate clay films on faces of peds. Many roots; mildly alkaline (pH 7.4); clear smooth boundary (8 to 10 inches thick).

B3--16 to 20 inches; brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; moderate medium prismatic structure that parts to moderate medium subangular blocky; soft, very friable, sticky and plastic, few roots; mildly alkaline (pH 7.6); clear smooth boundary (4 to 6 inches thick).

Clca--20 to 48 inches; light brownish gray (10YR 6/2) clay loam, grayish brown (10YR 4/2) moist, weak, medium prismatic structure that parts to weak, medium subangular blocky; soft, very friable, sticky and plastic; few roots moderately alkaline (pH 8.4); clear smooth boundary (20 to 30 inches thick).

C2ca--48 to 60 inches; light brownish gray (10YR 6/2) loam, grayish brown (10YR 4/2) moist; massive; soft, very friable, slightly sticky and slightly plastic; strongly alkaline (pH 8.5).

The A horizon has hue of 7.5YR or 10YR, value of 4 or 5 dry, 3 or 4 moist. The B horizon is commonly clay loam but ranges to silty clay loam. The C horizon is loam or very fine sandy loam.

Peyton Series

The Peyton series consists of deep, well drained soils that formed in Arkosica sands. Peyton soils are on rolling uplands and have slopes of 3 to 25 percent. The mean annual precipitation ranges from 13 to 16 inches and the mean annual soil temperature is 44 to 47° F.

Peyton soils are similar to Evanston, Cruckton, and Attewan soils. The Evanston soils are formed in calcareous parent material and have less than 45 percent sand in control section. The Cruckton soils have less than 18 percent clay in control section. The Attewan soils are over sandy skeletal material in the lower part.

Typical pedon of Peyton sandy loam, 3 to 12 percent slopes, is located in the NE¼ of SE¼, sec. 15, T. 10 N., R. 91 W.:

Al--0 to 6 inches; dark grayish brown, (10YR 4/2) sandy loam, very dark grayish brown (10YR 3/2) moist; weak medium subangular structure that parts to moderate medium granules; soft, very friable, nonsticky and nonplastic; many fine and medium roots; neutral (pH 6.8); clear smooth boundary (4 to 8 inches thick).

B1--6 to 10 inches; dark brown (10YR 4/3) coarse sandy loam, dark brown (10YR 3/3) moist; weak coarse subangular structure that parts to weak medium subangular blocky; slightly hard, very friable nonsticky and nonplastic; very few thin clay films as bridges between sand grains and in root channels; many fine and medium roots; neutral (pH 6.9); clear smooth boundary (2 to 8 inches thick).

B2t--10 to 21 inches, brown (7.5YR 5/4) coarse sandy clay loam, dark brown (7.5YR 4/4) moist; moderate medium prismatic structure that parts to moderate medium subangular blocky; extremely hard, friable, slightly sticky and nonplastic; many thin clay films on faces of peds; many fine, few medium roots; neutral (pH 7.0) gradual smooth boundary (8 to 14 inches thick).

B3--21 to 29 inches; light yellowish brown (10YR 6/4) coarse sandy loam, yellowish brown (10YR 5/4) moist; weak coarse subangular blocky structure that parts to weak medium subangular blocky; extremely hard, very friable slightly sticky and nonplastic; very few thin clay films on faces of some peds and as bridging between sand grains; few fine roots; neutral (pH 7.0); gradual wavy boundary (4 to 10 inches thick).

C1--45 to 60 inches; yellow (10YR 7/6) loamy coarse sand, brownish yellow (10YR 6/6) moist; single grained; extremely hard, very friable, nonsticky and nonplastic, neutral (pH 7.0) (0 to several feet thick).

The A horizon has a value of 4 or 5 dry, 2 or 3 moist, and chroma of 2 or 3 dry and moist. The B horizon has a hue of 10YR or 7.5YR, value of 5 or 6 dry, 3 through 5 moist, and chroma of 3 through 6 dry and moist. Typically, the texture is sandy clay loam but clay ranges from 18 to 35 percent and sand from 45 to 75 percent. Coarse sand being predominant.

The angular sand tends to pack on drying giving a much harder dry consistency than normal for similar textures. The soils are noncalcareous throughout but may have carbonates in noncontinuous horizons below 40 inches.

Forelle Series (Borollic Haplargid, fine loamy mixed)

The Forelle series consists of deep, well drained soils that formed in aeolian deposit. Forelle soils are on gently sloping to steep uplands and have slopes of 3 to 25 percent. The mean annual precipitation ranges from 12 to 15 inches and the mean annual soil temperature is 42 to 47° F.

Forelle soils are similar to Evanston and Rock River soils. Evanston soils have a mollic epipedon. Rock River contains more than 50 percent fine or coarser sand in the control section.

Typical pedon of Forelle loam, 3 to 12 percent slopes, is located 1320 feet west of SE corner sec. 32, T. 7 N., R. 90 W.:

Ap--0 to 5 inches; grayish brown (10YR 5/2) loam, very dark grayish brown (10YR 3/2); weak fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; mildly alkaline (pH 7.4); clear smooth boundary (4 to 6 inches thick).

B1--5 to 10 inches; light brownish gray (10YR 6/2) loam, dark grayish brown (10YR 4/2) moist; weak coarse subangular blocky structure that parts to moderate medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; mildly alkaline (pH 7.4); clear smooth boundary (4 to 8 inches thick).

B2t--10 to 26 inches; light brownish gray (10YR 6/2) clay loam, dark grayish brown (10YR 4/2) moist, moderate, medium prismatic structure that parts to moderate, medium subangular blocky; slightly hard, friable, sticky and plastic; many moderately thick clay films on faces of peds; mildly alkaline (pH 7.4); clear smooth boundary (12 to 18 inches thick).

B3ca--26 to 30 inches; light brownish gray (10YR 6/2) clay loam, dark grayish brown (10YR 4/2) moist; weak, medium prismatic structure that parts to weak medium subangular blocky; slightly hard, friable, sticky and plastic; mildly alkaline (pH 7.8); clear smooth boundary (4 to 6 inches thick).

Cca--30 to 60 inches; light brownish gray (10YR 6/2) loam, dark grayish brown (10YR 4/2) moist massive structure; soft, very friable, nonsticky and nonplastic; moderately alkaline (pH 8.0).

The A horizon has hue of 10YR, value of 3 to 4 moist, chroma 2 or 3 dry and moist. This horizon is commonly loam but ranges to silt loam. The B horizon has hue of 10YR, value 5 or 6 dry, 4 or 5 moist, and chroma of 2 or 3 dry and moist. The B horizon is clay loam or silty clay loam and averages 24 to 35 percent clay. The C horizon is medium textured and may contain up to 40 percent very fine sand.

31--Busby Series (Borollic Camborthid, coarse loamy mixed)

The Busby series consists of deep, well drained soils that formed in sandy alluvium and colluvium. Busby soils are on sideslopes and fans and have slopes of 5 to 30 percent. The mean annual precipitation ranges from 12 to 15 inches and the mean annual soil temperature is 42 to 47° F.

The Busby soils are similar to the Unson and Dahlquist soils. The Unson soils have more than 35 percent coarse fragments in control section and occur in a drier climate. The Dahlquist soils have B2t horizon, and contain more than 35 percent coarse fragments.

Typical pedon of very fine sandy loam, 5 to 12 percent slopes, is located 2700 feet east, 1800 feet south of center, sec. 14, T. 6 N., R. 91 W.:

A1--0 to 2 inches; pale brown (10YR 6/3) very fine sandy loam, yellowish brown (10YR 5/4) moist; weak fine granular structure; soft, very friable, slightly sticky and nonplastic; slightly effervescent; mildly alkaline (pH 7.4); clear smooth boundary (2 to 4 inches thick).

B21--2 to 6 inches; pale brown (10YR 6/3) fine sandy loam, yellowish brown (10YR 5/4) moist; weak coarse prismatic structure that parts to weak medium subangular blocky; soft, friable, slightly sticky and slightly plastic; strongly effervescent; mildly alkaline (pH 7.6); clear smooth boundary (3 to 7 inches thick).

B22--6 to 12 inches; brown (10YR 5/3) very fine sandy loam, dark brown (10YR 4/3) moist; weak coarse prismatic structure that parts to weak medium subangular blocky; soft, friable, slightly sticky and slightly plastic; strongly effervescent; mildly alkaline (pH 7.8); gradual smooth boundary (4 to 8 inches thick).

C1--12 to 60 inches; pale brown (10YR 6/3) fine sandy loam, yellowish brown (10YR 5/4) moist; massive; soft, friable, slightly sticky and slightly plastic; violently effervescent; moderately alkaline (pH 8.0).

Thickness of the solum ranges from 9 to 19 inches. Hue ranges from 7.5YR through 2.5Y.

The A horizon has value of 6 or 7 dry, 5 or 6 moist, and chroma of 2 through 4. Texture is sandy loam or loam. The B horizon has value of 5 or 6 dry, 4 or 5 moist, and chroma of 2 through 4. Texture is sandy loam or loam. The C horizon has value of 5 or 6 dry, 4 or 5 moist, and chroma of 2 through 4. Texture is sandy loam or loam.

Yamac Series (Borollic Camborthid, fine loamy, mixed)

The Yamac series consists of deep, well drained soils that formed in weathered sandstone, siltstone and windlain materials. Yamac soils are on upland ridges and benches and have slopes of 5 to 30 percent. The mean annual precipitation ranges from 12 to 15 inches and the mean annual soil temperature is 42 to 47° F.

Yamac soils are similar to Forelle and Busby soils. Forelle soils have argillic horizons. Busby soils have less than 18 percent clay.

Typical pedon of Yamac loam, 5 to 9 percent slopes, is 500 feet west of the NE corner of sec. 18, T. 4 N., R. 93 W.:

A1--0 to 5 inches; pale brown (10YR 6/3) loam, brown (10YR 5/3) moist; weak fine granular structure; slightly hard, very friable, sticky and plastic; calcareous; moderately alkaline (pH 8.4); clear smooth boundary (3 to 7 inches thick).

B2--5 to 15 inches; pale brown (10YR 6/3) loam, olive brown (2.5Y 4/4) moist, light olive brown (2.5Y 5/4) crushed moist; moderate medium subangular blocky structure parting to moderate fine subangular blocky structure; hard, friable, sticky and plastic; calcareous; moderately alkaline (pH 8.2); gradual wavy boundary (8 to 12 inches thick).

C1--15 to 22 inches; pale brown (10YR 6/3) loam, light olive brown (2.5Y 5/4) moist; weak coarse subangular blocky structure; hard, friable, sticky and plastic; calcareous; moderately alkaline (pH 8.2); clear smooth boundary (5 to 12 inches thick).

C2--22 to 38 inches; very pale brown (10YR 7/3) loam, light olive brown (2.5Y 5/4) moist; weak coarse subangular blocky structure; slightly hard, friable, sticky and plastic; calcareous; moderately alkaline (pH 8.2); clear smooth boundary (15 to 25 inches thick).

C3--38 to 60 inches; very pale brown (10YR 7/3) loam; massive structure; hard, friable, sticky and plastic; calcareous; moderately alkaline (pH 8.4).

The A horizon ranges in hue from 7.5YR through 2.5Y, in value from 3 or 4 moist, 5 or 6 dry, and in chroma from 2 through 4 moist and dry. The texture is commonly loam to silt loam. The B horizon has the same hue, value, and chroma ranges as the A horizon, and ranges in texture from loam to light clay loam.

35--Tisworth Series

The Tisworth series consists of deep, well drained soils that formed in alluvium and residuum weathered from sandstone and shale. Tisworth soils are on upland benches, terraces, and fans and have slopes of 0 to 9 percent. The mean annual precipitation ranges from 12 to 15 inches and the mean annual soil temperature is 42 to 47° F.

Tisworth soils are similar to Absher soils. Absher soils have more than 35 percent clay in the control section.

Typical pedon of Tisworth fine sandy loam, 5 to 9 percent slopes, is located 200 feet west of the center of the SE $\frac{1}{2}$ of sec. 30, T. 5 N., R. 92 W.:

A2--0 to 3 inches; pale brown (10YR 6/3) fine sandy loam, dark brown (10YR 4/3) moist; moderate medium platy structure parting to moderate fine plates; soft, very friable, nonsticky and nonplastic; calcareous; strongly alkaline (pH 8.8); abrupt wavy boundary.

B2t--3 to 13 inches; light yellowish brown (10YR 6/4) light clay loam, dark brown (10YR 4/3) moist; moderate coarse subangular blocky structure parting to moderate medium subangular blocky structure; hard, friable, sticky and plastic; few thin clay films on ped faces; calcareous; very strongly alkaline (pH 9.6); abrupt smooth boundary.

B3--13 to 18 inches; pale brown (10YR 6/3) light clay loam, dark brown (10YR 4/3) moist; moderate medium subangular blocky structure breaking to moderate fine subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; calcareous; moderately alkaline (pH 8.4); clear wavy boundary.

C1--18 to 37 inches; light yellowish brown (10YR 6/4) light clay loam, yellowish brown (10YR 5/4) moist; moderate medium subangular blocky structure parting to moderate medium granular structure; hard, friable, slightly sticky and slightly plastic; calcareous; strongly alkaline (pH 8.6); clear smooth boundary.

C2--37 to 60 inches; light brownish gray (2.5Y 6/2) sandy loam, light olive brown (2.5Y 5/4) moist; weak coarse subangular blocky structure parting to single grain structure; soft, friable, slightly sticky and nonplastic; calcareous; moderately alkaline (pH 8.4).

The A2 horizon has hues of 10YR to 2.5Y, values of 6 or 7 dry, 4 or 5 moist, and chroma of 1 through 3. It is sandy loam or loam in texture. The B2t horizon has hue of 2.5Y through 7.5YR, value of 4 through 6 dry, 3 through 5 moist, and chroma of 2 through 4. It has weak to strong prismatic or columnar structure and is light clay loam or silty clay loam in texture. The exchangeable sodium ranges from 15 to 30 percent. The C horizon ranges in texture from sandy loam to clay loam, with some fine gypsum crystals. Up to 20 percent gravel occurs in some horizons in some areas.

47--Unnamed Series

The Unnamed (47) series consists of deep, well drained soils that formed in material weathered from shale. Unnamed (47) soils are on toeslopes and sideslopes of ridges and have slopes of 3 to 15 percent. The average annual precipitation is about 12 to 14 inches, the average annual

air temperature is about 40 to 45° F., and the frost-free season is about 80 to 100 days. Elevations are 6200 to 7400 feet.

The Unnamed (47) soils are similar to the Kemmerer and Bulkley soils and are located near the Tisworth, Relsob, and Cushool soils. Kemmerer and Cushool soils have soft shale or sandstone at 20 to 40 inches. Bulkley soils have deep wide cracks when dry. Relsob soils have less than 35 percent clay in the control section. Tisworth soils have a salt-affected layer.

Typical pedon of Unnamed (47) clay loam, 3 to 15 percent slopes, about 9 miles southeast of Great Divide, is 1200 feet south and 300 feet west of the northeast corner of sec. 17, T. 8 N., R. 92 W.:

A1--0 to 2 inches; brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; weak coarse platy parting to moderate fine platy structure; slightly hard, friable, sticky and plastic; slightly acid; abrupt smooth boundary.

B1--2 to 4 inches; brown (10YR 5/3) clay loam, dark yellowish brown (10YR 4/4) moist; moderate medium subangular blocky structure; hard, firm, sticky and plastic; calcareous; mildly alkaline; clear smooth boundary.

B2--4 to 13 inches; yellowish brown (10YR 5/4) clay, dark yellowish brown (10YR 4/4) moist; moderate coarse prismatic parting to moderate coarse subangular blocky structure; very hard, very firm, very sticky and very plastic; moderately alkaline; clear smooth boundary.

B3ca--13 to 21 inches; pale brown (10YR 6/3) clay, dark yellowish brown (10YR 4/4) moist; moderate coarse subangular blocky structure; hard, firm, sticky and plastic; calcareous; mildly alkaline; common visible seams and streaks of lime; clear smooth boundary.

Clca--21 to 33 inches; light brownish gray (2.5Y 6/2) sandy clay loam, grayish brown (2.5Y 5/2) moist; massive; slightly hard, friable, sticky and plastic; calcareous; mildly alkaline; few visible seams and streaks of lime; gradual smooth boundary.

C2--33 to 60 inches; light brownish gray (2.5Y 6/2) sandy clay loam, grayish brown (2.5Y 5/2) moist; massive; slightly hard, friable, slightly sticky and slightly plastic; calcareous; mildly alkaline.

The A horizon ranges in thickness from 0 to 5 inches, having been removed in some areas by erosion. Content of coarse fragments ranges from 0 to 10 percent by volume in the C horizon.

The A horizon has hue of 2.5Y through 7.5YR, value of 4 or 5 dry, 3 or 4 moist, and chroma of 2 or 3. The B horizon has hue of 2.5Y through 7.5YR, value of 4 through 6 dry, 3 through 5 moist, and chroma of 2 through 4. Textures are commonly clay but range from clay loam to silty clay. C horizon has hue of 2.5Y through 7.5YR, value of 4

through 6 dry, 3 through 5 moist, and chroma of 2 through 6. Textures are commonly sandy clay loam but range from sandy clay loam to clay. Reaction is slightly acid to moderately alkaline.

62--Rock River Series (Borollic Haplargids, fine loamy mixed)

The Rock River series consists of deep, well drained soils that formed in sandy outwash and alluvium. Rock River soils are on sloping uplands and have slopes of 3 to 65 percent. The mean annual precipitation ranges from 14 to 16 inches and the mean annual soil temperature is 45 to 47° F.

Rock River soil is similar to Forelle, Dahlquist, Evanston, and Peyton soils. The Forelle soils have less than 50 percent fine and coarser sand in the control section. Dahlquist soils have more than 35 percent coarse fragments in the control section. The Evanston have less than 50 percent fine and coarser sand in its control section and has mollic epipedons.

Typical pedon of fine sandy loam, 3 to 12 percent slopes, at W¼ corner, sec. 23, R. 96 W., T. 7 N.:

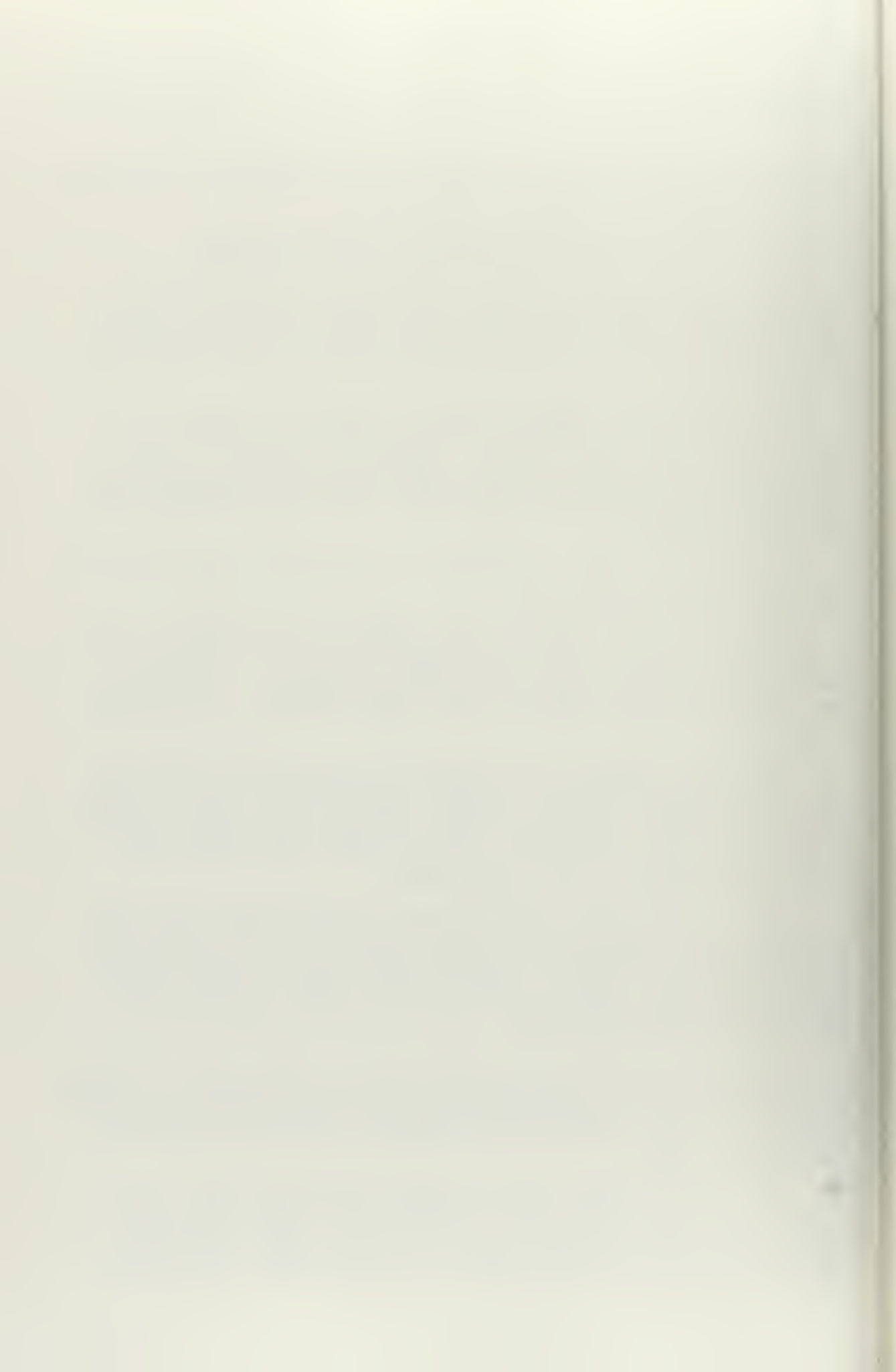
A1--0 to 2 inches; yellowish brown (10YR 5/4) fine sandy loam, dark brown (10YR 3/3) moist; weak medium granular structure that parts to single grains; soft and loose, very friable, nonsticky, and nonplastic; few fine roots; neutral (pH 7.2); clear smooth boundary (2 to 6 inches thick).

B2lt--2 to 5 inches; brown (10YR 5/3) fine sandy clay loam, dark yellowish brown (10YR 4/4) moist; weak medium prismatic structure that parts to weak medium subangular blocky; slightly hard, friable, slightly sticky, and slightly plastic; few thin clay films as bridging between sand grains and in root channels; few fine roots; neutral (pH 7.2); clear smooth boundary (0 to 6 inches thick).

B22t--5 to 10 inches; dark brown (10YR 4/3) fine sandy clay loam, dark brown (10YR 4/3) moist; weak medium prismatic structure that parts to moderate medium subangular blocky; slightly hard, friable, slightly sticky and slightly plastic; common thin clay films on faces of peds; few fine and medium roots; mildly alkaline (pH 7.4); gradual smooth boundary (4 to 10 inches thick).

B3--10 to 19 inches; dark brown (7.5YR 3/4) coarse sandy loam, dark brown (7.5YR 4/4) moist; weak medium subangular blocky structure; slightly hard, very friable, nonsticky, and nonplastic; few fine roots in upper part of the horizon; mildly alkaline (pH 7.8); gradual wavy boundary (5 to 12 inches thick).

Clca--19 to 32 inches; brown (7.5YR 5/4) fine sandy loam, light brown (7.5YR 6/4) moist; massive; slightly hard, friable, nonsticky, and nonplastic; visible calcium carbonate in form of common medium seams; strongly effervescent; mildly alkaline (pH 7.8); gradual wavy boundary (8 to 20 inches thick).



C2ca--34 to 60 inches; light brown (7.5YR 6/4) sandy loam, brown (7.5YR 5/4) moist; massive; loose, very friable, nonsticky, and nonplastic; visible disseminated calcium carbonate and few thin threads; violently effervescent; moderately alkaline (pH 8.0).

The A horizon has value of 5 or 6 dry, 3 or 4 moist, and chroma of 2 through 4 dry and moist. Texture is loam, fine sandy loam, or sandy loam. The B horizon has a hue of 7.5YR or 10YR, value of 4 or 5 dry, 3 or 4 moist, and chroma of 2 through 4 dry and moist. This horizon contains over 50 percent fine or coarser sand. Texture is generally a fine sandy clay loam. Clay content ranges from 20 to 32 percent. Coarse fragments range from 0 to 15 percent.

66--Relsob Series (Borollic Haplargid, fine-loamy, mixed)

The Relsob series consists of deep, well drained soils that formed in mixed residuum from sandstone. Relsob soils are on hillsides and have slopes of 3 to 15 percent. The average annual precipitation is about 12 to 14 inches, the average annual air temperature is about 40 to 46° F., and the frost-free season is 80 to 100 days. Elevations are 6200 to 7400 feet.

Relsob soils are similar to Forelle, Rock River, and Cushool soils and are located near Cushool, Unnamed (X66), and Unnamed (67) soils. Forelle and Rock River soils have accumulations of calcium carbonate above 40 inches. Cushool has soft shale and sandstone at less than 40 inches. Unnamed (X66) has greater than 35 percent clay in the control section. Unnamed (67) is sandy in the control section.

Typical pedon of Relsob loamy sand, 3 to 15 percent slopes, about 4 miles northwest of Great Divide, 400 feet west and 800 feet north of the southeast corner of sec. 10, T. 10 N., R. 94 W.:

A1--0 to 3 inches; dark brown (10YR 4/3) loamy sand, dark brown (10YR 3/3) moist; weak fine granular structure; soft, very friable; noncalcareous; mildly alkaline; clear smooth boundary.

B1--3 to 8 inches; brown (10YR 5/3) sandy loam, dark brown (10YR 4/3) moist; weak medium subangular blocky parting to weak fine granular structure; slightly hard, very friable, slightly sticky and slightly plastic; noncalcareous; mildly alkaline; clear smooth boundary.

B2lt--8 to 18 inches; yellowish brown (10YR 5/6) sandy clay loam, yellowish brown (10YR 5/4) moist; moderate medium subangular blocky parting to weak fine granular structure, slightly hard, friable, slightly sticky and slightly plastic; many thin clay films on faces of peds and in pores; noncalcareous; mildly alkaline; clear wavy boundary.

B22t--18 to 35 inches; yellowish brown (10YR 5/6) sandy clay loam, yellowish brown (10YR 5/6) moist; strong coarse subangular blocky parting to strong medium subangular blocky structure; hard, friable, slightly

C2ca--34 to 60 inches; light brown (7.5YR 6/4) sandy loam, brown (7.5YR 5/4) moist; massive; loose, very friable, nonsticky, and nonplastic; visible disseminated calcium carbonate and few thin threads; violently effervescent; moderately alkaline (pH 8.0).

The A horizon has value of 5 or 6 dry, 3 or 4 moist, and chroma of 2 through 4 dry and moist. Texture is loam, fine sandy loam, or sandy loam. The B horizon has a hue of 7.5YR or 10YR, value of 4 or 5 dry, 3 or 4 moist, and chroma of 2 through 4 dry and moist. This horizon contains over 50 percent fine or coarser sand. Texture is generally a fine sandy clay loam. Clay content ranges from 20 to 32 percent. Coarse fragments range from 0 to 15 percent.

66--Relsob Series (Borollic Haplargid, fine-loamy, mixed)

The Relsob series consists of deep, well drained soils that formed in mixed residuum from sandstone. Relsob soils are on hillsides and have slopes of 3 to 15 percent. The average annual precipitation is about 12 to 14 inches, the average annual air temperature is about 40 to 46° F., and the frost-free season is 80 to 100 days. Elevations are 6200 to 7400 feet.

Relsob soils are similar to Forelle, Rock River, and Cushool soils and are located near Cushool, Unnamed (X66), and Unnamed (67) soils. Forelle and Rock River soils have accumulations of calcium carbonate above 40 inches. Cushool has soft shale and sandstone at less than 40 inches. Unnamed (X66) has greater than 35 percent clay in the control section. Unnamed (67) is sandy in the control section.

Typical pedon of Relsob loamy sand, 3 to 15 percent slopes, about 4 miles northwest of Great Divide, 400 feet west and 800 feet north of the southeast corner of sec. 10, T. 10 N., R. 94 W.:

A1--0 to 3 inches; dark brown (10YR 4/3) loamy sand, dark brown (10YR 3/3) moist; weak fine granular structure; soft, very friable; noncalcareous; mildly alkaline; clear smooth boundary.

B1--3 to 8 inches; brown (10YR 5/3) sandy loam, dark brown (10YR 4/3) moist; weak medium subangular blocky parting to weak fine granular structure; slightly hard, very friable, slightly sticky and slightly plastic; noncalcareous; mildly alkaline; clear smooth boundary.

B2lt--8 to 18 inches; yellowish brown (10YR 5/6) sandy clay loam, yellowish brown (10YR 5/4) moist; moderate medium subangular blocky parting to weak fine granular structure, slightly hard, friable, slightly sticky and slightly plastic; many thin clay films on faces of peds and in pores; noncalcareous; mildly alkaline; clear wavy boundary.

B22t--18 to 35 inches; yellowish brown (10YR 5/6) sandy clay loam, yellowish brown (10YR 5/6) moist; strong coarse subangular blocky parting to strong medium subangular blocky structure; hard, friable, slightly

sticky and slightly plastic; many thin clay films on faces of peds and in pores; noncalcareous; mildly alkaline; clear wavy boundary.

B3--35 to 39 inches; brownish yellow (10YR 6/6) coarse sandy loam, brownish yellow (10YR 6/6) moist; moderate coarse subangular blocky structure; slightly hard, friable, slightly sticky and slightly plastic; common thin clay films on faces of peds and in pores; noncalcareous; mildly alkaline; clear wavy boundary.

C--39 to 60 inches; yellow (10YR 7/6) coarse sand, brownish yellow (10YR 6/6) moist; single grain; loose; noncalcareous; mildly alkaline.

Depth of the solum ranges from 11 to 39 inches. Depth to secondary lime accumulation is greater than 40 inches.

The A1 horizon has hue of 10YR, value of 4 or 3 dry, 3 or 4 moist, and chroma of 2 or 3. Texture is sandy loam or loamy sand. The B horizon has hue of 10YR, value of 4 through 6 dry, 4 or 5 moist, and chroma of 4 through 6. Textures are sandy clay loam or sandy loam; with more than 35 percent fine or coarser sand. The C horizon has hue of 10YR, value of 6 through 8 dry, 6 or 7 moist, and chroma of 4 through 6. Texture is loamy sand, sand, or coarse sand.

Unnamed (67) Series (Ustic Torripsamment, mixed, frigid)

The Unnamed (67) series consists of deep, excessively drained soils that formed in material weathered from sandstone. Unnamed (67) soils are on ridgetops and upper sideslopes and have slopes of 10 to 20 percent. The average annual precipitation is about 12 to 15 inches, the average annual air temperature is about 40 to 45° F., and the frost-free season is about 80 to 100 days. Elevations are about 6200 to 7400 feet.

The Unnamed (67) soils are similar to the Yetull and Zeona soils and are located near the Relsob, Cushool, and Unnamed (X66) soils. Yetull soils are calcareous. Zeona soils have fine sand predominating in the control section. Relsob and Cushool soils have more than 18 percent clay in the control section. Unnamed (X66) soils have more than 35 percent clay in the control section.

Typical pedon of Unnamed (67), 12 to 15 percent slopes, about 3 miles west of Great Divide, is 500 feet south and 400 feet east of the northwest corner of sec. 36, T. 10 N., R. 94 W.:

A1--0 to 3 inches; dark yellowish brown (10YR 4/4) sandy loam, dark brown (10YR 3/3) moist; weak fine subangular blocky structure; soft, very friable, slightly sticky and nonplastic; neutral; clear smooth boundary.

C2--3 to 10 inches; brownish yellow (10YR 6/6) sand, yellowish brown (10YR 5/6) moist; single grain; loose; neutral; clear smooth boundary.

C2--10 to 28 inches; yellow (10YR 7/6) sand, yellowish brown, (10YR 5/6) moist; single grain; loose; noncalcareous; mildly alkaline; clear smooth boundary.

C3--28 to 35 inches; yellow (10YR 8/6) sand, brownish yellow (10YR 6/6) moist; single grain; loose; calcareous; mildly alkaline; gradual wavy boundary.

C4--35 to 60 inches; brownish yellow (10YR 6/6) sand, yellowish brown (10YR 5/8) moist; single grain; loose; calcareous; mildly alkaline.

Thickness of the solum ranges from 3 to 6 inches. Depth to secondary line accumulations ranges from 30 to greater than 60 inches. Coarse fragments in the C horizon range from 5 to 15 percent by volume, and are predominantly less than $\frac{1}{2}$ inch in diameter. Reaction is neutral to mildly alkaline.

The A horizon is commonly sandy loam, but ranges to loamy sand. It has value of 4 or 5 dry, 3 or 4 moist, and chroma of 2 through 4. The C horizon is loamy coarse sand or sand. It has value of 6 through 8 dry, 5 through 7 moist, and chroma of 3 through 6.

Homelake Series (Fluvaquentic Haploborolls, fine loamy, mixed)

The Homelake series consists of deep, somewhat poorly drained soils that formed in mixed alluvium. Homelake soils are on floodplains and drainageways and have slopes of 0 to 3 percent. The mean annual precipitation ranges from 12 to 15 inches and the mean annual soil temperature is 42 to 47° F.

Homelake soils are similar to Brycan soils. Brycan soils are well drained and occur on upland toeslopes and swales.

Typical pedon of Homelake loam, 0 to 3 percent slopes, near center, SW $\frac{1}{4}$, sec. 33, T. 7 N., R. 92 W.:

A11--0 to 3 inches; dark reddish gray (5YR 4/2) loam, dark reddish brown (5YR 2/2) moist; few fine faint dark reddish brown (5YR 4/4) mottles; weak medium granular structure that parts to weak fine grains; soft, very friable, nonsticky and nonplastic; calcareous; mildly alkaline (pH 7.4); clear smooth boundary (3 to 6 inches thick).

A12--3 to 10 inches; gray (5YR 5/1) loam, very dark gray (5YR 3/1) moist; weak medium and coarse prismatic structure that parts to weak medium and coarse subangular blocky; soft, very friable, slightly sticky and slightly plastic; calcareous; mildly alkaline (pH 7.6); clear smooth boundary (5 to 8 inches thick).

C1--10 to 20 inches; dark gray (5YR 4/1) loam, black (5YR 2/1) moist; massive; soft, very friable, slightly sticky and slightly plastic; calcareous; neutral (pH 7.2); clear smooth boundary (7 to 12 inches thick).

C2--20 to 24 inches; gray (5YR 5/1) very fine sandy loam, very dark gray (5YR 3/1) moist; massive; soft, very friable, nonsticky and nonplastic; calcareous; mildly alkaline (pH 7.6); clear smooth boundary (0 to 6 inches thick).

C3g--24 to 30 inches; gray (5YR 5/1) loam, very dark gray (5YR 3/1) moist; many medium prominent (5Y 5/1) mottles; massive; soft, very friable, nonsticky and nonplastic; calcareous; moderately alkaline (pH 8.0); clear smooth boundary (6 to 15 inches thick).

C4g--30 to 60 inches; gray (5YR 5/1) silty clay loam, very dark gray (5YR 3/1) moist; common medium prominent (5Y 5/1) mottles; massive; slightly hard, friable, sticky and plastic; calcareous; moderately alkaline (pH 8.0).

The A horizons have hue of 5YR through 10YR, value of 3 through 5 dry, 2 or 3 moist, and chroma of 1 through 3 moist and dry. Mottles are typically absent. Texture is commonly loam, but ranges from silt loam to light fine sandy clay loam. The C horizons have hue of 5YR through 10YR, value of 4 through 6 dry. Texture is commonly loam or sandy loam, but stratifications ranging in texture from loamy sand to clay may be present. Faint to prominent mottles occur within 20 to 36 inches of the surface. Depth to free water ranges from 20 to 40 inches, and may be somewhat shallower during the spring and fall.

Kemmerer Series (Borollic Camborthid fine montmorillonitic)

The Kemmerer series consists of moderately deep, well drained soils that formed in residuum weathered from shale. Kemmerer soils are on upland shale ridges and benches in sideslope and ridge crest positions, and have slopes of 3 to 25 percent. The mean annual precipitation ranges from 12 to 15 inches and the mean annual soil temperature is 42 to 45° F.

Kemmerer soils are similar to Abor soils. Abor soils have higher percentages of clay in the subsoil and tend to crack when dry.

Typical pedon of Kemmerer silty clay loam, 5 to 10 percent slopes, is located 800 feet west and 100 feet south of the northeast corner of sec. 18, T. 4 N., R. 93 W.:

A1--0 to 3 inches; light brownish gray (2.5Y 6/2) light silty clay loam, dark grayish brown (10YR 4/2) moist; weak fine granular structure; hard, firm, sticky and plastic; mildly alkaline (pH 7.6); clear smooth boundary (2 to 4 inches thick).

B2--3 to 15 inches; light brownish gray (2.5YR 6/2) clay, [10 percent yellowish brown (10YR 5/6) weathered shale fragments], olive brown (2.5Y 4/4) moist; moderate medium subangular blocky breaking to weak medium subangular blocky structure; hard, firm, sticky and plastic; calcareous; moderate alkaline (pH 8.0); clear wavy boundary (10 to 16 inches thick).

Clcs--15 to 22 inches; light brownish gray (2.5Y 6/2) heavy silty clay loam, light olive brown (2.5Y 5/4) moist; moderate medium platy structure; hard, firm, sticky and plastic; calcareous; moderate alkaline (pH 8.0); clear wavy boundary (5 to 10 inches thick).

C2r--22 inches; weathered light brownish gray (2.5Y 6/2) calcareous shale.

The A horizon has a value of 4 or 5 moist, 5 or 6 dry, and a chroma of 2 to 4 moist and dry. The texture is commonly silty clay loam or clay loam but ranges to silt loam. The B horizon has a value of 4 or 5 moist, 5 or 6 dry, and a chroma of 2 to 4 moist and dry. The texture is clay or silty clay and averages from 38 to 50 percent clay. The C horizon is commonly heavy silty clay loam but ranges to a light clay loam.

Moyerson Series [Ustic Torriorthents, clayey, montmorillonitic (calcareous) frigid, shallow]

The Moyerson series consist of shallow, well drained soils that formed in Wasatch or Lewis shale and may have a basalt overburden. Moyerson soils are on ridgetops and valley sideslopes and have slopes of 12 to 65 percent.

The mean annual precipitation ranges from 12 to 15 inches and the mean annual soil temperature is 42 to 47° F.

Moyerson soils are similar to Abor and Bulkley soils. Abor soils are 20 to 40 inches deep over shale. Bulkley soils have shale at depths over 40 inches.

Typical pedon of Moyerson stony loam, 25 to 65 percent slopes, NW¼, NW¼, sec. 2, T. 6 N., R. 90 W.:

A1--0 to 3 inches; grayish brown (10YR 5/2) stony loam, very dark grayish brown (10YR 3/2) moist; weak fine granular structure; soft very friable; slightly sticky and slightly plastic; 30 percent basalt stones; neutral; gradual wavy boundary (2 to 5 inches thick).

C--3 to 14 inches; light brownish gray (10YR 6/2) clay, dark grayish brown (10YR 4/2) moist; weak medium subangular blocky structure; slightly hard, firm, sticky and plastic; strongly effervescent; mildly alkaline; gradual wavy boundary (8 to 15 inches thick).

Cr--14 inches plus; strongly effervescent fractured Lewis shale.

Depth to shale ranges from 10 to 20 inches. Basalt overburden may be absent. Hue ranges from 7.5YR through 2.5Y.

The A horizon has value of 5 through 7 dry, 3 through 5 moist, and chroma of 2 through 4. Texture ranges from fine sandy loam to heavy clay loam. Basalt stones may make up 20 to 40 percent of the horizon.

The C horizon has value of 5 through 7 dry, 4 through 6 moist, and chroma of 2 through 4. Texture is heavy clay loam or clay.

Yetull Series (Ustic Torripsamments, mixed, frigid)

The Yetull series consists of deep, excessively drained soils that formed in calcareous eolian sands. Yetull soils are on upland sandhills and have slopes of 5 to 30 percent. The mean annual precipitation ranges from 12 to 15 inches and the mean annual soil temperature is 44° to 47° F.

Yetull soils are similar to Zenoa soils. The Zenoa soils are noncalcareous throughout.

Typical pedon of loamy sand, undulating near W¼ corner, sec. 18, T. 7 N., R. 96 W.:

A1--0 to 3 inches; light brownish gray (10YR 6/2) loamy sand, dark grayish brown (10YR 4/2) moist; weak fine granular structure; soft, very friable, nonsticky and nonplastic; many fine and medium roots, slightly effervescent; mildly alkaline (pH 7.4); clear smooth boundary (2 to 8 inches thick).

C--3 to 60 inches; very pale brown (10YR 7/3) fine sand, brown (10YR 5/3) moist, weak fine granular structure in upper part becoming single grained with depth, soft, very friable, nonsticky and nonplastic; many fine and medium roots to about 12 inches, few fine roots below that; violently effervescent; moderately alkaline (pH 8.0) (5 to many feet thick).

The A horizon has a value of 6 through 8, 5 or 6 moist, and chroma of 2 or 3 dry and moist. Typically the A horizon is calcareous but may be leached in some pedons. The C horizon has a hue of 2.5Y or 10YR, value of 6 through 8 dry, 4 through 6 moist, and chroma of 2 through 4 dry or moist. The sands are typically fine but may range from fine through coarse. Reaction ranges are moderate or strongly alkaline.

Ryan Park Series (coarse-loamy, mixed Borollic Haplargid)

The Ryan Park series consist of deep, somewhat excessively drained soils formed in materials weathered from sandstone. Ryan Park soils are on nearly level to strongly sloping alluvial fans and hills and have slopes of 0 to 15 percent. The mean annual precipitation is 12 to 15 inches, the mean annual soil temperature is 45 to 46° F., and the frost-free season is 75 to 95 days.

Ryan Park soils are similar to Forelle and Rock River soils. Forelle and Rock River soils contain more than 18 percent clay in the B2 horizons.

Typical pedon of Ryan Park sandy loam, 0 to 5 percent slopes:

A1--0 to 5 inches; yellowish brown (10YR 5/4) sandy loam, dark yellowish brown (10YR 3/3) moist; weak fine crumb structure; loose, very friable, nonsticky and nonplastic; mildly alkaline (pH 7.4); clear smooth boundary (2 to 7 inches thick).

B1--5 to 13 inches; brown (10YR 5/3) sandy loam, dark brown (10YR 4/3) moist; weak medium subangular blocky structure that parts to weak fine granules; slightly hard, very friable, nonsticky and slightly plastic; few thin clay films on faces of peds; mildly alkaline (pH 7.4); clear smooth boundary (5 to 9 inches thick).

B2t--13 to 23 inches; yellowish brown (10YR 5/4) sandy loam, dark yellowish brown (10YR 4/4) moist; moderate coarse prismatic structure that parts to moderate medium subangular blocky; slightly hard, friable, nonsticky and slightly plastic; common thin clay films on faces of peds; mildly alkaline (pH 7.6) clear smooth boundary (8 to 12 inches thick).

B3ca--23 to 30 inches; pale brown (10YR 6/3) sandy loam brown (10YR 4/3) moist; weak coarse subangular blocky structure that parts to weak medium subangular blocky; slightly hard, very friable, nonsticky and slightly plastic; few thin clay films on faces of peds; moderately alkaline (pH 8.0); gradual wavy boundary (4 to 19 inches thick).

Clca--30 to 37 inches; light gray (10YR 7/2) sandy loam, pale brown (10YR 6/3) moist; weak coarse subangular blocky structure; slightly hard, very friable, nonsticky and nonplastic; moderately alkaline (pH 8.4) abrupt wavy boundary (5 to 15 inches thick).

IIC2ca--37 to 39 inches; very pale brown (10YR 7/3) gravelly sandy loam, yellowish brown (10YR 5/4) moist; massive; slightly hard; very friable; nonsticky and nonplastic; 20 percent gravel; moderately alkaline (pH 8.4); abrupt smooth boundary.

IIC3--39 to 60 inches; very pale brown (10YR 7/4) sand, yellowish brown (10YR 5/4) moist; single grain; loose, nonsticky and nonplastic; mildly alkaline (pH 7.6).

The A horizon has a hue of 10YR, a value of 5 or 6 dry, 4 or 5 moist, and a chroma of 2 or 3. The texture is a sandy loam or loamy sand. The B horizons have a hue of 10YR or 7.5YR, a value of 5 or 6 dry, 4 or 5 moist, and a chroma of 3 or 4. The texture is a sandy loam. The C horizons have hues of 10YR, a value of 6 or 7 dry, 5 or 6 moist, and a chroma of 3 or 4. The texture is a sandy loam, loamy sand, or sand.

Soil Survey Interpretations

Data on the soil survey interpretations can be obtained from the State Office of the Soil Conservation Service.

APPENDIX E
GREENHOUSE STUDY

FINAL REPORT

ON

CHARACTERIZATION OF SOIL AND GEOLOGIC
MATERIALS OVERLYING COAL SEAMS
AS PLANT GROWTH MEDIA

FOR

LAY CREEK, COLORADO
EMRIA STUDY SITE

Submitted to:

United States Department of the Interior
Bureau of Reclamation
Denver, Colorado

Submitted by:

Robert D. Heil and Paul C. Deutsch
Department of Agronomy
Colorado State University
Fort Collins, Colorado 80523

July 1980

INTRODUCTION

This report describes the results of a study conducted for the Bureau of Reclamation to characterize soil and geological overburden materials from the EMRIA Lay Creek, Colorado study site.

The study reported herein is a portion of a larger overburden characterization study being made jointly by the Bureau of Reclamation and Colorado State University.

The objectives of this portion of the study were:

1. Laboratory characterization to describe the geochemical nature of soil and geologic overburden materials.
2. Greenhouse growth studies and accompanying plant tissue analyses to determine the potential opportunities and/or constraints that these materials offer as plant growth media.
3. Post-harvest laboratory analyses to determine any changes in the chemical nature of the material as a result of the greenhouse experiment.

PART I

PROCEDURES

Laboratory Procedures

Following are the laboratory methods used to analyze the soil and geologic material for those properties selected as a basis for determining plant growth suitability.

Extractable Phosphorus

Determined on a spectrophotometer from a sodium bicarbonate extract. The values are reported in parts per million P and are an index of available P.

Exchangeable Potassium

Determined on the atomic absorption spectrophotometer from an ammonium acetate extract. The values are reported as parts per million K.

Organic Matter

Determined by wet oxidation with spontaneous heat of reaction. The results are determined colorimetrically and reported as percent organic matter (% O.M.).

Plant Available Zinc, Iron, Manganese and Copper, Cadmium, Nickel and Lead

Determined on the atomic absorption spectrophotometer from an extracting solution of diethylenetriamine pentaacetic acid (DTPA). The results are reported in parts per million of Zn, Fe, Mn, Cu, Cd, Ni, and Pb.

Salinity (Electrical Conductivity)

Determined by a solu-bridge from a saturation extract. The results are reported as electrical conductivity in millimhos per centimeter (mmhos/cm).

Exchangeable Sodium Percentage (ESP)

Determined by atomic absorption spectrophotometer and calculated by:

$$ESP = \frac{\text{Exchangeable sodium meq/100 gm}}{CEC} \times 100$$

Cation Exchange Capacity (CEC)

Determined by:

$$\text{CEC meq/100g} = \frac{\text{Exchangeable Na meq/l} \times 10}{\text{weight of sample in grams}}$$

Sodium Adsorption Ratio (SAR)

Prepared from a saturation extract read on the atomic absorption spectrophotometer and determined by:

$$\text{SAR} = \frac{\text{Na}}{\sqrt{\frac{\text{Ca} + \text{Mg}}{2}}}$$

pH

Determined with a combination electrode pH meter on a saturated soil paste.

Total Arsenic, Selenium, Boron and Molybdenum

Determined by hot water extractable method on the atomic absorption spectrophotometer.

Plant Analysis

Plants were digested with perchloric acid and determinations run on the atomic absorption spectrophotometer.

Plant Nitrogen

Determined by the Tecator Block method and read by titration after distillation. Recorded as % N.

Greenhouse Procedures

Soil and geologic material received from the Bureau of Reclamation laboratory had been ground to approximately 2 mm size for greenhouse and additional chemical analyses. One kilogram of soil was used per pot and each pot was replicated. Each sample was placed in a plastic bag in a round container and assigned a greenhouse identification number.

Fertilizer Treatment

Before planting, fertilizer was applied at a rate of 150 ppm nitrogen as reagent grade NH_4NO_3 ; 80 ppm of phosphorus as a combination of KH_2PO_4 and $\text{Ca}(\text{H}_2\text{PO}_4)_2$. H_2O and 80 ppm potassium as KH_2PO_4 . This was done along with preplant watering.

Before the fertilizer was added, 50-100 g of soil was removed from each pot after which the fertilizer and water was put on. Additional N was applied at 50 ppm rate 21 days after seedling emergence.

Planting

The pots were planted with 75 seeds of western wheatgrass (Agropyron smithii var. arriba). The seeds were evenly distributed in the pots and covered with the soil that was removed before fertilization.

The pots were covered with plastic to reduce evaporation and were checked daily to assure that the soil remained moist.

After planting, unseasonably hot weather was experienced with temperatures in the greenhouse being well over 100° F. This seemed to deter germination almost 100 percent. After a 20-day period with virtually no germination, we replanted, placing 60 seeds on top of the soil and covering with vermiculite. This new planting was successful.

In this experiment, we did not thin the plants, hoping to have an average of 60 plants per pot. After consulting other researchers involved in similar work as well as from our own experience, we felt that 60 plants would not put undue stress on the pot and our yields would show more significant differences. This would also give us more plant material for plant analysis. An average of 58 plants per pot was calculated for the complete experiment.

Daily Management

All pots were weighed every other day and brought to field capacity with distilled water. The greenhouse lights were set to allow 15-16 hours of daylight.

Pots were rotated on a regular basis to allow for changes in temperature and lighting within the greenhouse. All pots were randomly arranged on the table.

Seven days after germination, our plants were hit with a fungus with some kill-back on a few pots. We treated this for a two-week period by burning sulfur at night. After the two-week treatment, the plants outgrew the fungus problem.

Harvest

Generally, we harvest at approximately 48 days after planting, but due to germination and fungus problems combined with a week of cloudy weather, we allowed these plants to go 57 days before harvesting.

The plants were cut at about 2 cm above the soil surface. Plants were then placed in brown paper bags and dried at 60° C for 48-60 hours in a forced air oven. After drying, the plants were weighed and weights recorded.

Statistical Analysis

Cluster analysis of selected data was performed on all the samples from the Lay Creek Site. The data set used to perform the analysis consisted of pH, organic matter percent, salinity, exchangeable sodium percentage and totals of sand, silt, and clay. This particular set of data was used because the criteria for evaluating these variables are thought to be very reliable. The results of the initial cluster analysis are shown in Table 1.

The purpose of performing a cluster analysis was to statistically develop groups of samples which showed a high degree of association within each group and a low degree of association between groups. The representative groups which were developed served as a pool for selecting samples to perform post-harvest analyses.

Criteria for Evaluation

The properties considered and criteria used for making suitability interpretations are shown in Table 2.

Evaluating Toxic Elements

The toxic elements considered and evaluated in this study are those thought to be of most importance from the standpoint of toxicity to plant, fish, animals and man.

Toxicity of these elements to plants, animals and man have been reported for some elements, but in most cases, well accepted critical levels have not been established.

Our approach in this study has been to evaluate soil, geologic and plant tissue analyses data to determine if levels are approaching what the current state of the art is relative to potential toxicity problems and then identifying and discussing a particular problem on a sample by sample basis. Our sources of literature for making these evaluations are listed on page 183.

The current thought by our group is that there is insufficient criteria available for establishing interpretive guidelines for evaluating potential toxicity problems as was done for other factors identified in Table 2. The "state of the art knowledge" dictates that we evaluate toxicity problems on a sample by sample-element by element basis using the most current and what appears to be the most applicable information available at this particular time. Sources of information utilized for making our evaluations are listed on page 183.

Table 1
Initial groups developed from cluster analysis

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8
DH-1 #1	DH-1 #3	DH-2 #3	DH-2 #4	DH-2 c	DH-3 c	DH-3 e	DH-3 i
DH-1 #2	DH-1 #4	DH-4 #3		DH-2 d	DH-3 d	DH-3 h	DH-3 m
DH-1 b	DH-1 a	DH-4 #4		DH-2 h	DH-3 f	DH-3 k	DH-4 k
DH-2 e	DH-2 #2			DH-2 j	DH-3 j	DH-3 n	
DH-2 f	DH-2 a			DH-2 k	DH-3 o	DH-4 l	
DH-2 i	DH-2 b			DH-3 l	DH-4 b		
DH-3 #1	DH-2 g				DH-4 c		
DH-4 #1	DH-3 #2				DH-4 d		
DH-2 #1 control	DH-3 #3				DH-4 e		
	DH-3 a				DH-4 f		
	DH-3 b				DH-4 g		
	DH-4 #2				DH-4 h		
	DH-4 #5				DH-4 i		
	DH-4 a				DH-4 j		
					DH-4 m		
					DH-3 g		

Table 2
Criteria for evaluating laboratory characterization
data for determining plant growth suitability

Texture ^{1/}		pH ^{1/}		Available phosphorus ^{2/}		Available potassium ^{2/}		Available zinc ^{2/}		Available iron ^{2/}		Available copper and manganese ^{2/}		Salinity ^{3/}		Sodium ^{4/}		
				Soil test (ppm P)	Soil phosphorus fertility status	Soil test (ppm K)	Soil potassium fertility status	Soil test (ppm Zn)	Availability status	Soil test (ppm Fe)	Availability status	Soil test (ppm Cu or Mn)	Availability status	Soil test (mmhos/cm)	Rating	Exchange- able sodium percent	Rating	
Very fine sandy loam	(vfs1)	Good	6.0-8.4	Good	0.7	Deficient	0-60	Deficient	0-0.5	Potentially deficient	0-2.0	Potentially deficient	0-0.5	Potentially deficient	0-4	Acceptable	0-10	Acceptable
Fine sandy loam	(fsl)	Good	5.0-6.0; 8.4-8.9	Fair	>7	Adequate	>60	Adequate	>.5	Adequate	>2.0	Adequate	>.5	Adequate	4-8	Marginal	10-15	Marginal
Sandy loam	(sl)	Good	<5.0; >8.9	Poor											>8-12	Poor to unsuitable	>15	Nonacceptable
Loam	(l)	Good																
Silt loam	(sil)	Good																
Loamy fine sand	(lfs)	Fair																
Loamy sand	(ls)	Fair																
Clay loam	(cl)	Fair																
Sandy clay loam	(scl)	Fair																
Silty clay loam	(sicl)	Fair																
Sand	(s)	Poor																
Clay	(c)	Poor																
Sandy clay	(sc)	Poor																
Silty clay	(sic)	Poor																

^{1/} Criteria for evaluating the overburden characteristics were developed using proposed guidelines developed by the Western Regional Soil Survey Work Planning Committee on "Guidelines for Evaluating Soil and Overburden Characteristics in Strip-Mine Reclamation."

^{2/} Criteria are based on current Colorado State University Soil Testing Laboratory soil interpretation guidelines.

^{3/} Based on Bureau of Reclamation Land Suitability Classification Salinity Evaluation.

^{4/} From "Procedures Recommended for Overburden and Hydrologic Study of Surface Mines" (Heil, Deutsch, et al, 1979).

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PART II

PLANT GROWTH SUITABILITY EVALUATION BASED ON LABORATORY CHARACTERIZATION

This portion of the evaluation and characterization study involved two steps. An initial evaluation was performed to identify the chemical and/or physical problems associated with the materials that influence plant growth. This resulted in the development of "Problem Identification Categories." Secondly, the "Problem Identification Categories" were further grouped into what are described as "Problem Area Groups." The purpose of this latter grouping was to identify particular problem areas such as fertility, salinity, pH, texture, etc., which are more meaningful for evaluating the magnitude of potential long term management and environmental concerns. Following is described the evaluation process used for interpreting plant growth suitability on the basis of laboratory characterization data.

Development of Problem Identification Categories

Basic to determining plant growth suitability is the identification of the specific kinds of problems that affect the use of a material for this purpose. First, it is essential to evaluate these chemical and physical properties most important in affecting plant growth. Next, criteria must be established for making a suitability interpretation. The properties considered and criteria used for interpretation in this part of the study are shown in Table 2 on page 182. The chemical and physical data used for this evaluation are shown in Table 8 on page 194. This step in the evaluation process resulted in the identification of 26 "Problem Identification Categories" which are described in Table 3.

A study of these categories indicates that the following specific kinds of limitations exist in terms of the suitability of the materials as plant growth media.

1. Phosphorus and/or potassium deficiencies are common to nearly all samples.
2. Micronutrient deficiencies are common with deficiencies in copper being the most common. It is important to point out that the criteria used for evaluating micronutrient deficiencies are based on deficiencies associated with agronomic crops sensitive to these elements. Thus, the micronutrient deficiencies must be considered somewhat arbitrary. Overall, we suspect that micronutrients would not be a major fertility problem.
3. Texture has been identified as being a potential concern with a large number of samples. High runoff potential

Table 3
Description of "Problem Identification Categories"

Problem identification categories	Site Sample Number	Description
1	DH-1 #1, DH-1 #4, DH-2a, DH-2b, DH-2c, DH-2e	P--deficient
2	DH-1 #3, DH-2 #1, DH-2 #2, DH-2g, DH-2i	P--deficient; pH--fair
3	DH-2j	P--deficient; pH--poor; Cu and Mn--potentially deficient
4	DH-2h	P--deficient; Cu--potentially deficient; pH--poor
5	DH-1a	Texture--fair
6	DH-3 #1	P--deficient; texture--fair
7	DH-1b, DH-2f	P--deficient; texture--poor
8	DH-3 #2, DH-4 #1	P--deficient; pH--fair; texture--fair
9	DH-1 #2	P--deficient; Cu--potentially deficient; texture--fair
10	DH-3 #3	P--deficient; Cu--potentially deficient; pH--fair; texture--fair
11	DH-2d	P-K--deficient; pH--fair; Cu--potentially deficient; texture--fair
12	DH-3l	P-K--deficient; pH--poor; Cu--potentially deficient; texture--fair
13	DH-2K	P-K--deficient; Cu--potentially deficient; sodium--marginal
14	DH-4 #2	P--deficient; pH--fair; sodium--marginal
15	DH-4 #5	P--deficient; pH--fair; sodium--unacceptable
16	DH-3b, DH-3e, DH-3h, DH-3i, DH-3k, DH-3o, DH-4e	P--deficient; pH--poor; sodium--unacceptable
17	DH-3n	P-K--deficient; pH--poor; Cu--potentially deficient; sodium--unacceptable
18	Dh-4l	K--deficient; pH--poor; Cu--potentially deficient; sodium--unacceptable
19	DH-4 #3	Salinity--marginal; sodium--marginal
20	DH-4h, DH-4j, DH-4k	pH--fair; sodium--unacceptable; texture--fair
21	DH-3a	P--deficient; pH--poor; sodium--marginal; texture--poor
22	DH-4 #4	P--deficient; salinity--marginal; sodium--marginal
23	DH-2 #3	pH--fair; salinity--marginal; sodium--unacceptable
24	DH-2 #4	Fe and Cu--potentially deficient; salinity--poor; sodium--marginal
25	DH-3c, DH-4d, DH-4f, DH-4i, DH-4m	P--deficient; pH--poor; sodium--unacceptable; texture--poor
26	DH-3d, DH-3f, DH-3g, DH-3j, DH-3m, DH-4b, DH-4c, DH-4g, DH-4a	P--deficient; pH--poor; sodium--unacceptable; texture--fair

and erosion due to the slow infiltration rates of fine textured materials would be the major problem. The high runoff potential is a concern both as it affects environmental quality as well as plant growth.

4. Sodium problems are common to many materials.
5. High pH.--Some question could be raised concerning the utilization of pH as a single criteria for evaluating the suitability of materials. According to the criteria shown in Table 2, a number of materials would be rated poor based on high pH. Yet the yield data shown in Table 6 of this report would suggest that in several cases (compare yield and laboratory data for samples DH-2j and DH-2g), pH should not be used as an indicator of suitability. We developed the "Problem Identification Categories" and "Problem Area Groups" by strictly following the criteria shown in Table 2. Modification of our interpretations based on pH may be appropriate.

In summary, deficiencies in phosphorus, potassium and possibly copper; high levels of sodium; high pH; and texture appear to be the kinds of specific problems associated with the materials studied in terms of plant growth suitability.

Development and Description of "Problem Area Groups"

The development of "Problem Identification Categories" was the first step in evaluation of materials for plant growth media. Recognizing that some of these categories could be grouped on the basis of problem areas, i.e., fertility, texture, etc., we further grouped the categories into "Problem Area Groups." This grouping better identifies the magnitude of the kinds and combinations of problems and are also more meaningful from a management decision point of view.

Descriptions of the "Problem Area Groups" and the basis used for determining relative suitability rating are shown in Table 4.

A summary of relative suitability ratings by "Problem Area Groups" are shown in Table 5.

Table 4
Descriptions of "Problem Area Groups"

Problem area groups	Description and basis for suitability rating
1. Fertility, pH--fair	This group includes Problem Identification Categories 1 and 2. P-deficiency alone affects this group of materials as a plant growth media. These materials are suitable as plant growth media if fertilizers are added to eliminate the deficiency. These materials are classed as suitable.
2. Fertility, pH--poor	This includes categories 3 and 4 and is characterized by P-deficiency. The pH value is over 8.9. These materials are classed as questionable because of high pH.
3. Texture--fair	This includes category 5 and silty clay loam texture increases the material's potential erosiveness. This material is classified as suitable.
4. Fertility, texture--fair	This includes category 6 and is characterized by P-deficiency and clay loam texture. Problems due to erosion may be a problem. This material may be suitable for plant growth if sufficient water is available and erosion controlled.
5. Fertility, texture--poor	This includes category 7 and is characterized by P-deficiency and clay textures. Clay materials have a high water erosion potential and if erosion occurs may affect environmental quality. These materials may be questionable due to potential erosion problems.
6. Fertility, texture--fair pH--fair	This includes categories 8, 9, 10, and 11 and is characterized by P alone or either with K and Cu deficiency. pH is fair and texture is clay loam or loamy sands. This increased susceptibility to erosion from either water (CL) or wind (LS). These materials are classified as questionable.
7. Fertility, pH--poor Texture--fair	This includes category 12 where there is P and K deficiency along with Cu potential deficiency. The pH is high, over 8.9 and the texture is a loamy sand susceptible to wind erosion and also may limit available water for plant growth. These materials are classified as questionable because of pH and texture.
8. Fertility, sodium-- marginal	This includes category 13 where there is a P-K deficiency along with potentially deficient Cu and a marginal sodium level. Marginal sodium level increases water erosion potential by reducing the amount of plant growth and decreasing infiltration rates, thus causing more runoff. Materials in this group are classified as unsuitable.
9. Fertility, pH--fair Sodium--marginal	This includes category 14. P-deficiency, marginal sodium and pH of 8.4-8.9 characterize this group. This material may be considered unsuitable because of potential effect of sodium.
10. Fertility, pH--fair to poor Sodium--marginal	This includes Problem Identification Categories 15, 16, 17, and 18. These include P or K alone or together with Cu potential deficiency, a pH of generally more than 8.9 and high sodium. Due to detrimental affects of sodium and high pH on plant growth and potential erosion problems caused by same, this group is classified as unsuitable.
11. Salinity--marginal Sodium--marginal	This includes Problem Identification Category 19 and is characterized by a conductivity of 4-8 mmhos/cm. Marginal salinity levels may affect plant growth unless salt tolerant species are selected. The materials are classed as questionable due to salinity and sodium.
12. pH--fair Sodium--unacceptable Texture--fair	This includes category 20 with pH of 8.4-8.9, high sodium levels and a clay loam or silty clay loams. Due to effect of high sodium, these materials are classified as unsuitable.
13. Fertility, pH--poor Sodium--marginal Texture--poor	This includes category 21 and is characterized by P-deficiency, pH of over 8.9, a moderate sodium and a silty clay. The high pH with an erosion potential caused by the moderate sodium in combination with the silty clay make this material unsuitable for plant growth.
14. Fertility, salinity-- marginal Sodium--marginal	This includes Identification Category 22 and is characterized by P-deficiency, a moderate salt and sodium problem. This material is classified questionable for plant growth.
15. pH--fair Salinity--marginal Sodium--unacceptable	This includes Problem Identification Category 23 and has a pH of 8.4-8.9, a moderate salinity, and very high sodium level making it unsuitable to all but very salt tolerant plant growth. This material is classified as unsuitable.
16. Fertility, salinity--poor Sodium--marginal	This includes Problem Identification Category 24 and is characterized by potential Cu and Fe deficiency along with salinity at a level over 8 mmhos/cm and moderate sodium levels. Due to erosion and salt problems these materials are classified as unsuitable.
17. Fertility, pH--poor Sodium--unacceptable Texture--fair to poor	This includes categories 25 and 26 and are seen to have P-deficiency along with very high pH over 8.9, high sodium (ESP 15 or over) and textures silty clays, clay, and clay loams. The combination of high sodium and poor textures tends to suggest permeability and erosion problems and makes these materials unsuitable for plant growth media.

Table 5
Summary of suitability ratings
developed on the basis of
laboratory characterization data

Problem Area Group Number	Relative rating
1	Suitable
2	Questionable
3	Suitable
4	Suitable
5	Questionable
6	Questionable
7	Questionable
8	Unsuitable
9	Unsuitable
10	Unsuitable
11	Questionable
12	Unsuitable
13	Unsuitable
14	Questionable
15	Unsuitable
16	Unsuitable
17	Unsuitable

PART III

POSTHARVEST EVALUATION

In addition to the physical and chemical data shown in Table 8 on page 194, analyses were carried out to identify and evaluate changes in chemical characteristics as a result of the weathering environment created in the greenhouse experiment. Postharvest analyses of selected samples consisted of plant available P and K; DTPA extractable Zn, Fe, Mn, Cu, Cd, Ni, and Pb; pH; electrical conductivity; cation exchange capacity; exchangeable sodium percentage; sodium adsorption ratios; and hot water extractable B, Mo, As, and Se. Representative samples, based on preharvest chemical analyses were selected from each of seven computer generated cluster analyses groups. Postharvest soil analyses results are shown in Table 9 on page 195.

A summary of the postharvest chemical analyses shown in Table 9 show the following important relationships.

1. The pH values of all selected samples show a marked decrease from preplant to postharvest. These changes range from 0.6 to 1.9 for the soil materials and 1.7 to 2.0 for the geologic overburden materials. We feel these changes are a result of high levels of CO₂ production by plant roots and a reaction product of carbonic acid forming when CO₂ and water are combined. In a field situation, this pH change would be restricted to the plant rooting zone and should be highly correlated to the amount of root biomass produced. These degrees of decrease in pH had not been observed in similar experiments conducted by ourselves where soil and geologic materials were being evaluated.
2. The preplant vs. postharvest electrical conductivities increased in all samples tested. The magnitude of increase for all but the surface soil samples (DH-1 #1; DH-4 #1; DH-2 #1; DH-1 #3) was great enough to shift the ratings to a lesser degree of suitability, i.e., acceptable materials became marginal; marginal materials became unsuitable, etc. It must be noted that the greenhouse pots were not freely drained, thus salts could accumulate. This may not happen in a well drained field situation. Thus, the rating of materials was not changed due to this factor.
3. In most cases the exchangeable sodium percentages (ESP), which are defined as the extent to which the adsorption complex of a material is occupied by sodium, decreased. These decreases ranged from 0.2 to 12.0 percent. The magnitude of decrease in each case was not large enough to shift the suitability ratings. It appears from preplant vs. postharvest ESP data that materials with initially

high values will remain at a critical level (marginal to nonacceptable) from a plant growth or environmental quality point of view. Likewise, materials with initially low ESP values will remain at a level that will not be detrimental to plant growth.

4. Postharvest analyses of the selected materials showed a reduction, from adequate to potentially deficient, in plant available zinc in the soil materials (DH-1 #1; DH-4 #1; DH-2 #1; DH-1 #3; DH-4 #5; DH-4 #4). Zinc levels remained at an adequate level in the geologic materials from preplant through postharvest period.
5. Extractable data on postharvest levels of Cd, Ni, Pb, B, Mo, As, and Se appear to be relatively low and do not indicate any potential problems. Levels of As and Se for all samples were below the detection limit of 0.5 ppm. It is important to note that even though extractable chemical analysis data closely approximate the actual soil solution condition, very little data is available that correlates plant uptake with extractable levels of elements, particularly with regard to native species.

PART IV

GREENHOUSE GROWTH STUDY AND PLANT TISSUE ANALYSES

Greenhouse growth studies along with plant tissue analyses were carried out to aid in evaluation of materials as plant growth media and to verify any performance and/or plant growth characteristics predicted from laboratory characterization data of the overburden materials studied.

The greenhouse growth study is described in Part I of this report as to methods and procedures. The results of this study are shown in Table 6 by sample within each "Problem Area Group." Yields reported reflect the mean value for all replications of the material.

The results of the greenhouse study appear to indicate the following.

1. Sodium (ESP) and/or salinity (EC) showed a depressing effect on yields as their concentrations increase in materials.
2. Materials affected only with fertility, pH and texture as potential problems showed consistently the highest yields for the experiment (Problem Area Groups 1, 3 and 4).
3. Materials in "Problem Area Groups" 8, 13, and 16 show yields approaching those of the best materials identified in 2 above. These groups are typified by being classed as marginal in regards to sodium but are only a percent or two above the acceptable limit set at 10 percent.
4. "Problem Area Group" 7 shows an average yield of 2.47 gram/pot. Materials within the group have textures of loamy sand thus were rated as questionable for plant growth because of droughtiness. The high yield values obtained show an important point with regard to greenhouse studies in that the environment created for plant growth is somewhat controlled with water, sunlight and fertility never lacking. Thus, as demonstrated through the material of "Problem Area Group" 7 greenhouse results may be misleading.

Plant tissue analyses data from selected materials are shown in Table 7. These selected samples correspond to the samples used for post-harvest laboratory analyses in Part III of this report.

A review of the plant tissue analyses data indicates the following.

1. Total zinc concentrations are higher in plants from the geologic overburden materials than those from soils. This

Table 6

Average yield values for samples within each problem area group

Problem Area Group	Sample Number	Average yield	Problem Area Group	Sample Number	Average yield
1	DH-1 #1	2.34	11	DH-4 #3	1.72
	DH-1 #4	2.56			
	DH-2a	2.37		DH-4h	1.38
	DH-2b	2.66	12	DH-4j	1.34
	DH-2c	1.54		DH-4k	1.65
	DH-2e	2.50			
	DH-1 #3	2.49	13	DH-3a	2.09
	DH-2 #1	2.02			
	DH-2 #2	2.31		DH-4 #4	1.44
	DH-2g	1.91	14		
2	DH-2i	2.05		DH-2 #3	1.81
	DH-2j	2.16	15	DH-2 #4	2.10
D					
	DH-2h	1.79			
			16	DH-3c	1.88
3	DH-1a	2.00		DH-4d	1.70
				DH-4f	1.81
				DH-4i	1.46
4	DH-3 #1	2.14		DH-4m	1.77
				DH-3d	1.77
				DH-3f	2.15
5	DH-1b	1.75		DH-3g	1.22
	DH-2f	1.96		DH-3j	1.71
				DH-3m	1.49
6	DH-3 #2	1.34		DH-4b	1.78
	DH-4 #1	1.60		DH-4c	1.59
	DH-1 #2	1.54		DH-4g	1.78
	DH-3 #3	1.46		DH-4a	1.20
	DH-2d	1.83			
7	DH-3l	2.47			
8	DH-2k	2.04			
9	DH-4 #2	1.85			
10	DH-4 #5	2.47			
	DH-3b	1.91			
	DH-3e	2.15			
	DH-3h	2.25			
	DH-3i	1.24			
	DH-3k	1.16			
	DH-3o	1.96			
	DH-4e	1.87			
	DH-3n	2.09			
	DH-4l	2.39			

Table 7
Analysis of plants grown on selected materials

Cluster	Sample No.	Percent					ppm								Nitrogen (percent)
		P	K	Ca	Mg	Na	B	Zn	Fe	Mn	Cu	Ni	Mo	Cd	
1	DH-1 #1 A	0.26	3.22	0.61	0.22	<0.01	5	12	56	68	6	<2	<2	<2	3.84
	B	.30	3.46	.61	.24	<.01	5	13	126	51	7	<2	<2	<2	3.84
	DH-4 #1 A	.26	3.36	.66	.33	.05	11	11	157	109	10	<2	<2	<2	3.89
	B	.29	3.72	.73	.38	.06	10	9	103	81	10	<2	<2	<2	3.79
	DH-2 #1 A	.24	3.36	.56	.20	<.01	14	19	48	78	6	<2	<2	<2	3.64
	Control B	.34	3.44	.48	.20	<.01	3	22	86	74	7	<2	<2	<2	3.64
2	DH-1 #3 A	.26	2.96	.35	.44	.03	27	7	102	166	10	2.5	14.1	<2	3.39
	B	.24	2.90	.30	.43	.03	26	7	75	164	11	2.6	13.1	<2	3.03
	DH-4 #5 A	.17	3.28	.39	.27	.14	9	14	76	112	10	2	<2	<2	3.56
	B	.14	3.22	.37	.27	.14	9	14	63	102	9	2.5	<2	<2	3.28
3	DH-4 #4 A	.24	3.35	.43	.33	.20	11	16	72	180	12	<4	<4	<4	3.92
	B	.20	3.42	.34	.28	.16	7	14	128	160	11	<2	<2	<2	3.89
5	DH-2h A	.26	3.75	.40	.19	.06	7	55	48	163	9	<4	<4	<4	4.56
	B	.18	3.55	.33	.19	.19	3	31	27	163	7	<4	<4	<4	3.05
	DH-31 A	.15	2.90	.54	.21	.07	46	37	103	111	7	<2	3.6	<2	3.42
	B	.14	2.98	.57	.20	.07	44	32	136	103	5	<2	2.2	<2	3.39
6	DH-3g A	.21	3.68	.33	.19	.19	15	30	231	177	9	<4	<4	<4	3.86
	B	.19	3.72	.31	.18	.26	15	33	105	159	9	<2	3.5	<2	3.86
	DH-4i A	.19	3.36	.24	.15	.17	10	41	74	108	11	<2	<2	<2	4.37
	B	.24	3.10	.22	.16	.18	3	49	89	93	12	<2	2.7	<2	4.20
7	DH-3h A	.18	3.26	.29	.16	.14	14	35	60	151	6	<2	3.6	<2	3.50
	B	.15	3.28	.27	.16	.15	10	29	101	190	6	<2	3.6	<2	3.16
8	DH-4K A	.16	3.34	.23	.19	.18	4	29	164	216	7	<2	3.9	<2	3.25
	B	.17	3.30	.24	.17	.16	6	27	112	179	8	<2	3.1	<2	2.49

Note: As, Se and Pb fell below 10 ppm (the detection limit).

Table 8
Laboratory characterization data
(preplant analyses)

Site Sample Number	Depth (feet)	pH	DTPA Ext. (ppm)				NaHCO ₃ P (ppm)	NH ₄ OAC K (ppm)	O.M. (percent)	ECx10 ³ (mmhos/ cm)	SAR	C.E.C. (meq/100g)	ESP	Percent		
			Fe	Zn	Mn	Cu								S	Si	C
DH-1 #1	0 - 0.5	8.0	12.0	2.8	5.1	0.80	0.30	144.0	2.20	0.27	0.2	15.06	0.9	53.4	28.8	17.8
DH-1 #2	0.5- 3.5	8.2	4.0	2.3	3.4	.40	.30	72.0	1.25	.41	.6	21.25	2.2	27.8	43.6	28.6
DH-1 #3	3.5- 7.0	8.9	3.8	2.2	1.6	.58	.30	98.4	.45	.75	5.7	18.44	7.7	32.6	40.2	27.2
DH-1 #4	7.0- 10.0	8.4	4.8	2.2	1.2	.76	.30	134.4	.55	2.99	5.1	18.75	6.7	33.4	41.8	24.8
DH-1 a	42.0- 50.6	<u>1/</u> 8.2	12.6	2.9	2.2	3.04	30.38	84.0	.85	1.02	.5	9.25	2.9	14.4	57.8	27.8
DH-1 b	52.5- 58.0	<u>1/</u> 7.8	29.4	5.5	16.4	3.72	0	122.4	1.70	2.08	.4	24.38	1.4	24.0	33.4	42.6
DH-2 #1	0 - .75	8.6	10.8	2.2	7.0	.84	0	187.2	1.70	.53	.3	18.63	1.2	48.2	31.6	20.2
Control																
DH-2 #2	0.75- 5.0	8.9	3.6	2.2	2.3	.56	0	69.6	.75	.56	4.9	17.94	7.2	35.2	40.8	24.0
DH-2 #3	5.0- 9.0	8.5	4.2	2.2	1.4	.68	31.88	91.2	.45	5.70	10.0	18.75	16.0	36.0	39.2	24.8
DH-2 #4	9.0- 10.0	8.0	3.4	2.2	1.0	.44	24.38	79.2	.40	8.62	8.1	17.06	11.0			
DH-2 a	27.1- 48.0	<u>1/</u> 8.3	12.0	3.2	21.0	3.80	0	88.8	1.20	1.67	1.0	17.56	2.1	10.0	55.0	35.0
DH-2 b	58.0- 75.0	8.3	30.0	3.8	1.2	3.52	0	72.0	.92	.99	.5	11.56	3.5	21.0	53.4	25.6
DH-2 c	75.0-129.5	8.4	21.0	3.1	1.6	.52	0	60.0	.50	1.28	.5	5.63	6.9	65.0	24.4	10.6
DH-2 d	129.5-146.9	8.6	22.2	2.4	1.3	.32	5.63	36.0	.20	1.02	.5	3.56	6.7	79.0	12.6	8.4
DH-2 e	166.5-177.3	8.3	40.8	2.9	3.6	.96	.38	103.2	1.10	1.05	.6	11.19	3.3	47.2	32.6	20.2
DH-2 f	177.3-204.5	8.4	36.6	5.6	1.2	11.80	0	300.0	1.40	1.45	1.8	47.25	1.9	17.8	28.2	54.0
DH-2 g	204.5-217.5	8.8	30.6	2.2	1.7	3.60	0	134.4	.55	1.15	4.6	15.88	5.6	22.4	53.4	24.2
DH-2 h	217.5-252.1	9.5	13.8	2.5	1.0	.32	0	96.0	.25	1.00	7.0	16.25	7.5	69.0	13.2	17.8
DH-2 i	252.1-263.8	8.9	19.2	4.0	1.4	1.08	0.38	120.0	1.10	1.36	5.4	11.75	6.1	53.8	28.2	18.0
DH-2 j	263.8-271.4	9.1	9.6	3.4	.5	.36	0	79.2	.20	1.27	4.7	9.38	7.4	71.6	14.6	13.8
DH-2 k	271.4-303.4	8.4	21.0	2.4	1.8	.36	0.38	28.8	.45	1.62	2.5	2.69	11.0	71.2	19.0	9.8
DH-3 #1	0 - 2.0	8.4	9.0	2.0	5.8	.80	0	117.6	1.05	.35	.3	23.94	.9	34.8	35.8	29.4
DH-3 #2	2.0- 5.0	8.6	4.6	1.9	3.7	.56	1.88	84.0	.55	.39	2.0	13.75	4.0	33.2	38.6	28.2
DH-3 #3	5.0- 10.0	8.8	6.1	2.0	5.8	.48	1.88	93.6	.28	.64	5.3	19.69	5.6	31.4	38.6	30.0
DH-3 a	13.6- 25.1	9.4	9.6	2.3	1.0	1.12	0	165.6	.20	1.44	14.0	33.75	12.0	17.4	42.4	40.2
DH-3 b	25.1- 28.6	9.4	17.4	2.3	4.6	.96	0	117.6	.40	1.89	13.0	11.00	16.0	25.2	52.4	22.4
DH-3 c	28.6- 38.7	9.8	39.6	2.3	4.5	10.00	0	187.2	.40	1.46	15.0	24.44	22.0	8.8	47.4	43.8
DH-3 d	40.5- 47.4	10.0	37.8	2.6	2.6	3.44	1.88	252.0	.28	1.03	16.0	33.75	36.0	23.2	41.2	35.6
DH-3 e	47.4- 55.0	9.9	42.0	2.3	1.8	2.80	.38	194.4	.15	1.12	15.0	20.13	37.0	48.0	27.4	24.6
DH-3 f	55.0- 65.2	9.9	48.6	3.8	6.3	11.00	0	204.0	.45	1.44	19.0	21.81	35.0	16.8	45.0	38.2
DH-3 g	65.2- 71.7	9.8	52.2	2.6	3.9	4.40	0	117.6	.40	1.63	25.0	10.19	35.0	33.6	47.8	18.6
DH-3 h	71.7- 86.9	9.9	40.2	3.3	2.4	.60	1.88	127.2	.25	1.86	24.0	23.44	39.0	57.0	25.2	17.8
DH-3 i	86.9-102.6	9.6	57.0	3.1	7.6	1.64	1.88	105.6	1.25	1.96	20.0	9.94	32.0	39.6	39.6	20.8
DH-3 j	102.6-123.9	9.9	34.2	3.0	1.4	6.20	2.63	196.8	.25	1.43	15.0	25.25	36.0	22.8	42.4	34.8
DH-3 k	123.9-164.1	9.8	31.8	2.8	3.8	3.16	1.88	96.0	.45	2.74	22.0	6.50	23.0	58.2	24.6	17.2
DH-3 l	164.1-184.2	9.1	18.0	2.6	2.5	.24	1.88	24.0	.28	1.75	6.1	12.50	3.6	81.8	11.4	6.8
DH-3 m	184.2-200.1	9.5	52.2	4.1	16.2	2.76	1.88	144.0	1.50	1.49	21.0	11.81	30.0	20.2	51.6	28.2
DH-3 n	200.1-210.9	9.1	19.8	2.7	2.5	.48	1.88	40.8	.70	1.76	17.0	2.38	26.0	67.8	22.8	9.4
DH-3 o	225.4-254.1	9.5	40.8	3.1	7.0	2.00	1.88	81.6	.70	2.10	35.0	3.44	44.0	24.2	50.2	25.6
DH-4 #1	0 - 1.8	8.6	28.2	2.2	13.8	1.04	0	144.0	1.10	.62	2.4	29.88	2.5	27.4	28.4	44.2
DH-4 #2	1.8- 3.0	8.8	4.7	2.0	1.4	.80	1.88	79.2	.70	1.82	10.0	26.31	12.0	23.8	36.8	39.4
DH-4 #3	3.0- 5.0	8.3	5.0	2.1	1.8	1.04	7.13	132.0	.45	6.29	12.0	26.25	12.0	26.0	36.6	37.4
DH-4 #4	5.0- 8.5	8.2	5.8	2.1	1.4	.84	2.63	156.0	.25	7.33	12.0	27.94	11.0	27.2	35.0	37.8
DH-4 #5	8.5- 13.0	8.5	5.2	2.1	1.3	.80	1.83	100.8	.25	3.17	14.0	17.00	16.0	22.0	48.4	29.6
DH-4 a	13.0- 22.6	9.4	10.2	2.0	1.8	.56	.38	100.8	.20	1.04	11.0	15.69	6.1	24.8	47.4	27.8
DH-4 b	22.6- 36.5	9.9	37.8	2.2	4.3	5.20	1.88	192.0	.20	1.02	14.0	22.25	27.0	16.0	45.4	38.6
DH-4 c	36.5- 47.2	9.8	40.2	4.7	15.2	6.60	1.88	134.4	.35	1.71	25.0	8.63	36.0	21.0	49.8	29.2
DH-4 d	47.2- 57.0	9.9	51.6	5.6	2.6	16.40	1.88	286.0	.45	2.21	27.0	35.06	39.0	18.2	36.6	45.2
DH-4 e	57.0- 66.3	10.0	36.0	2.2	5.0	3.16	1.88	108.0	.20	1.28	20.0	13.44	40.0	31.0	44.2	24.8
DH-4 f	66.3- 69.5	9.9	44.4	5.9	6.0	11.00	1.88	177.6	.50	1.40	19.0	22.50	37.0	27.6	24.6	47.8
DH-4 g	69.5- 74.0	9.9	42.0	3.9	5.84	6.80	2.63	136.8	.61	1.44	22.0	13.44	37.0	9.2	61.4	29.4
DH-4 h	74.0- 82.1	10.0	39.0	3.0	2.7	10.00	7.13	182.4	.20	1.39	21.0	21.25	42.0	32.6	33.6	33.8
DH-4 i	84.8- 92.5	10.0	43.2	5.0	3.7	14.40	2.63	211.2	.28	1.38	19.0	25.00	39.0	12.0	39.2	48.8
DH-4 j	95.5-111.3	9.7	58.2	3.1	3.8	8.00	7.13	163.2	.40	1.50	25.0	15.94	36.0	11.4	55.8	32.8
DH-4 k	111.3-120.4	9.9	52.8	3.5	19.0	3.16	10.13	139.2	1.80	1.64	24.0	13.75	34.0	11.8	59.8	28.4
DH-4 l	120.4-192.0	9.9	18.6	2.6	2.6	.40	10.13	57.6	.20	1.53	21.0	6.31	39.0	71.8	18.4	9.8
DH-4 m	192.0-223.2	9.8	58.8	5.1	3.0	8.40	7.63	218.4	1.10	1.70	23.0	28.75	38.0	15.2	42.6	42.2

1/ pH - 1:5 solution.

Table 9
Postharvest soil analysis on selected samples

Cluster	Sample Number	Plant available (ppm)		DTPA Ext. (ppm)							pH	ECx10 ³ (mmhos/cm)	C.E.C.	ESP	SAR	ppm	
		P	K	Zn	Fe	Mn	Cu	Cd	Ni	Pb						B	Mo
1	DH-1 #1	22	140	0.4	6.2	7.5	0.5	<0.1	0.6	0.5	7.4	2.0	15.7	<1.0	1.6	0.7	<0.05
	DH-4 #1	13	146	.3	7.7	8.5	1.0	<.1	.5	1.0	7.6	2.5	29.8	1.7	2.9	.7	<.05
	DH-2 #1	28	200	.4	12.7	37.4	.8	<.1	1.1	.7	6.7	2.8	16.7	<1.0	1.1	.7	<.05
Control																	
2	DH-1 #3	32	140	.1	2.0	8.3	.6	<.1	.4	.6	7.8	3.5	17.3	4.0	5.8	1.5	.35
	DH-4 #5	5	90	.3	4.8	3.9	.8	<.1	.2	1.3	7.5	5.1	15.0	12.7	13.2	.3	.05
3	DH-4 #4	1	167	.4	5.9	4.9	.9	<.1	.3	.7	7.6	10.2	26.2	11.5	13.0	.4	<.05
5	DH-2h	3	108	2.4	12.1	5.3	.8	<.1	.3	1.7	7.8	3.6	13.2	4.5	6.3	.4	<.05
	DH-3l	11	38	1.8	14.2	4.5	.3	<.1	.2	.5	7.2	4.8	1.4	7.1	4.0	.9	<.05
6	DH-3g	25	128	2.2	49.8	9.1	4.4	<.1	.1	2.4	8.1	6.0	13.7	31.4	31.3	.8	.06
	DH-4i	8	241	9.8	38.0	8.5	10.0	<.1	.4	6.5	8.1	5.8	25.4	30.3	36.3	1.0	.15
7	DH-3h	16	113	3.0	38.0	10.1	.9	<.1	.2	1.9	7.9	6.0	19.6	27.0	31.9	.8	.13
8	DH-4k	11	162	4.3	45.0	52.2	7.0	<.1	.9	1.7	7.9	7.3	15.4	26.6	27.6	.9	.34

Note: As and Se fell below the detection limit of <0.5 ppm.

correlates well with preplant vs. postharvest analyses which show a decrease in available zinc for soil materials and are unchanged or increase in geologic overburden material. Chapman (1966) reported zinc deficiency symptoms in oats and corn at levels of less than 20 ppm and 9-15 ppm respectively. While samples DH-1-1, DH-1-3, DH-4-1, and DH-4-5 are within this deficiency range, the wheatgrass grown showed no deficiency symptoms. It should be kept in mind that species vary greatly in their need and tolerance of micronutrients. Heil and Deutsch (1980)^{1/} have shown zinc response on western wheatgrass (Agropyron smithii) grown on soil and geologic overburden materials from the Bureau of Land Management's McCallum, Colorado site. Samples from Lay Creek appear to be very similar in physical and chemical characteristics to McCallum samples and therefore have the potential to be zinc deficient.

2. Total concentrations of the elements studied in plant tissue appear to be well within published tolerance ranges for most agronomic crops (Chapman 1966; Gough and Shacklette 1976) and therefore acceptable from a plant growth and environmental quality point of view.

It appears that good correlation exists between preplant, postharvest and plant tissue analyses on all samples tested. It appears that any changes which occurred as a result of weathering during the greenhouse experiment were not of a magnitude which would affect plant growth.

^{1/} Data to be presented in final report of the EMRIA-McCALLUM, Colorado site results.

APPENDIX F
WEATHERING STUDY

Weathering Tests Conducted on
Overburden Samples from
Lay Creek, Colorado-EMRIA Study Areas

United States Department of the Interior
Bureau of Reclamation
Engineering and Research Center
Materials Science Section
Denver, Colorado



RESULTS OF LABORATORY WEATHERING TESTS CONDUCTED
ON CORE SAMPLES FROM LAY CREEK, COLORADO^{1/}

Laboratory weathering and outdoor exposure tests were conducted on overburden core samples from the Lay Creek, Colorado, study area. The purpose of these tests was to determine which materials would break down sufficiently to allow for their possible use as planting media in revegetation of strip-mined areas.

Test Procedures

Specimens for the laboratory weathering and outdoor exposure tests were cut from core samples submitted by Mr. Greg Brockman, code D-737 on May 3, 1979.

The purpose of including outdoor exposure tests was to determine if any correlation could be drawn between this type of weathering and the laboratory weathering conditions.

A laboratory weathering cycle consisted of the following conditions.

1. 8 hours at 23.9° C (75° F), 100 percent relative humidity (wetting/thawing)
2. 16 hours (64 hours on weekends) at 37.8° C (100° F), 10 percent relative humidity (drying)
3. 8 hours at 23.9° C (75° F), 100 percent relative humidity (wetting)
4. 16 hours (64 hours on weekends) at -17° C (0° F) (freezing)

In this study, core specimens about 50 mm (2 in) in diameter by 50 mm (2 in) in length were used. For testing and handling, the core specimens were placed on a No. 10 mesh screen in 400-ml plastic beakers.

Laboratory weathering tests were started on June 11, 1979, and 20 laboratory weathering cycles were completed on August 9, 1979. Outdoor exposure tests commenced on June 8, 1979, and will continue for one year.

Test Results

Test results are summarized in table L-1, and shown visually in figures L-1 through L-9.

^{1/} Progress Report FY-80.

At completion of the laboratory weathering tests, a percent breakdown value (%BD) was determined for the specimens. This value listed under the remarks column in the table was derived as follows.

$$\%BD = \frac{(TW - IW)}{TW} (100)$$

where TW = total specimen weight
IW = weight of original specimen remaining intact after testing

Of the nine samples tested, two sandstone materials (L-2 and L-9 exhibited little or no breakdown at all.

The following materials appeared to have broken down sufficiently to be considered for possible use as planting media: sandstone samples L-3 and L-5; and shale samples L-4 and L-6.

With regard to the outdoor exposure tests, the samples exhibited very little change during the three months of summer weathering. These samples will be evaluated and photographed after one year of exposure (June 1980) and the results furnished at that time to code D-737.

Table L-1
Weathering tests
Core samples from Lay Creek, Colo.

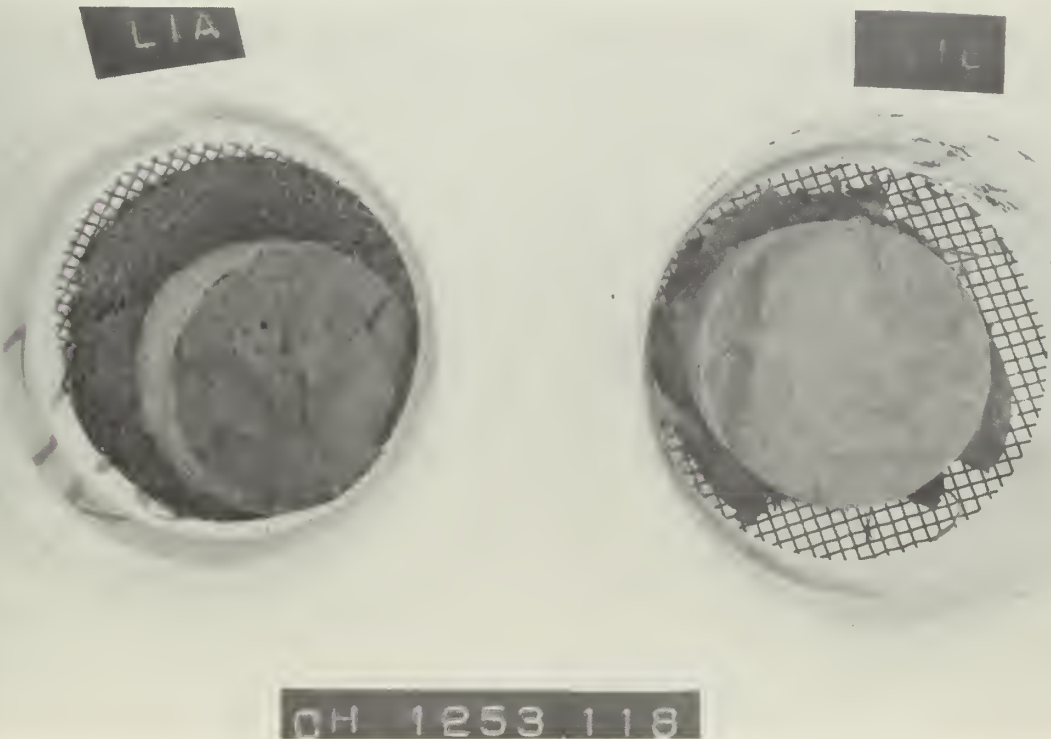
Laboratory Sample Number	Sample I.D.		Depth (feet)	Remarks			
	Sample			Laboratory weathering	%BD	Outdoor	Reference
L-1	Shale	DH-1	42.0- 50.6	Some slaking at 20 cycles.	38	No change at 3 months.	See Figure L-1
L-2	Sandstone	DH-1	84.5-110.8	No change at 20 cycles.	0	No change at 3 months.	See Figure L-2
L-3	Sandstone	DH-2	129.5-146.9	Scouring at 15 cycles. Considerable weathering at 20 cycles.	100	No change at 3 months.	See Figure L-3
L-4	Shale	DH-2	177.3-204.9	Some slaking at 5 cycles. Considerable slaking at 15 cycles.	100	Slight slaking at 3 months.	See Figure L-4
L-5	Sandstone	DH-3	71.7- 86.9	Considerable slaking at 5 cycles.	100	Some cracking at 3 months.	See Figure L-5
L-6	Shale	DH-3	102.6-123.9	Considerable slaking at 5 cycles.	100	Some cracking and slight slaking at 3 months.	See Figure L-6
L-7	Siltstone	DH-3	225.4-254.1	Some surface slaking at 5 cycles. Some delamination at 15 cycles.	61	No change at 3 months.	See Figure L-7
L-8	Siltstone	DH-4	95.5-111.3	Some surface slaking and delamination at 5 cycles. Considerable slaking at 15 cycles.	100	Some surface slaking at 3 months.	See Figure L-8
L-9	Sandstone	DH-4	120.4-192.0	No change at 20 cycles.	0	No change at 3 months.	See Figure L-9

Figure L-1

Results of weathering tests for shale sample L-1. Specimen A subjected to 20 laboratory weathering cycles; specimen B subjected to 3 months of outdoor exposure.



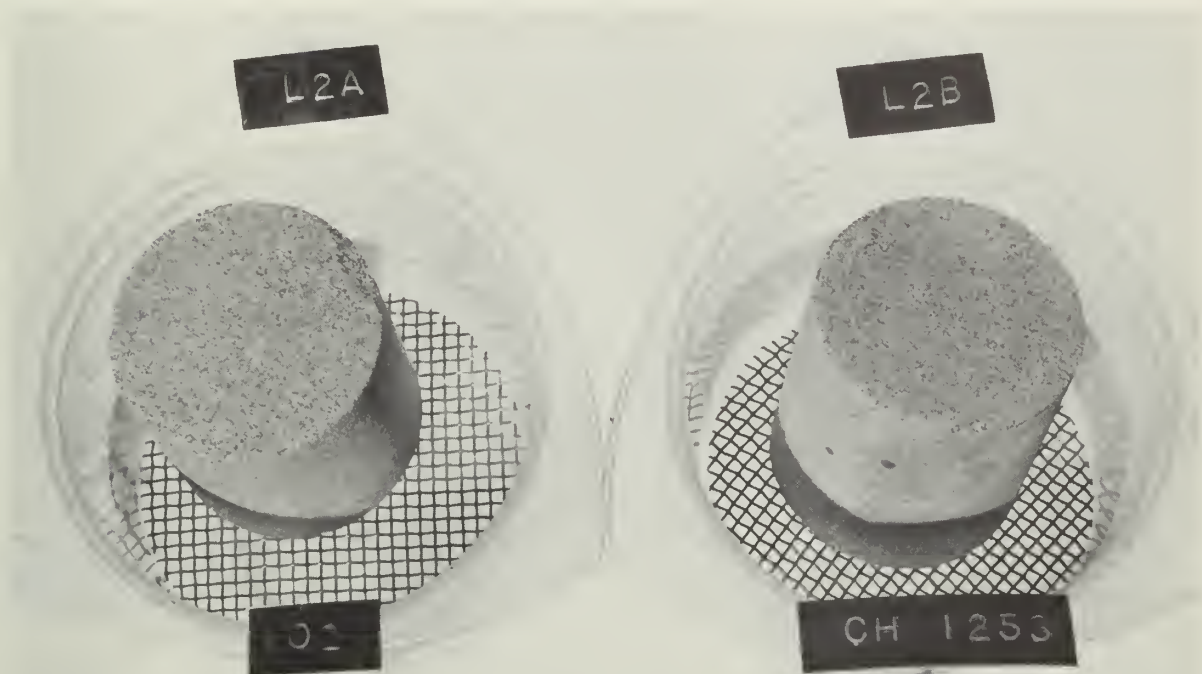
a. Original condition of test specimens.



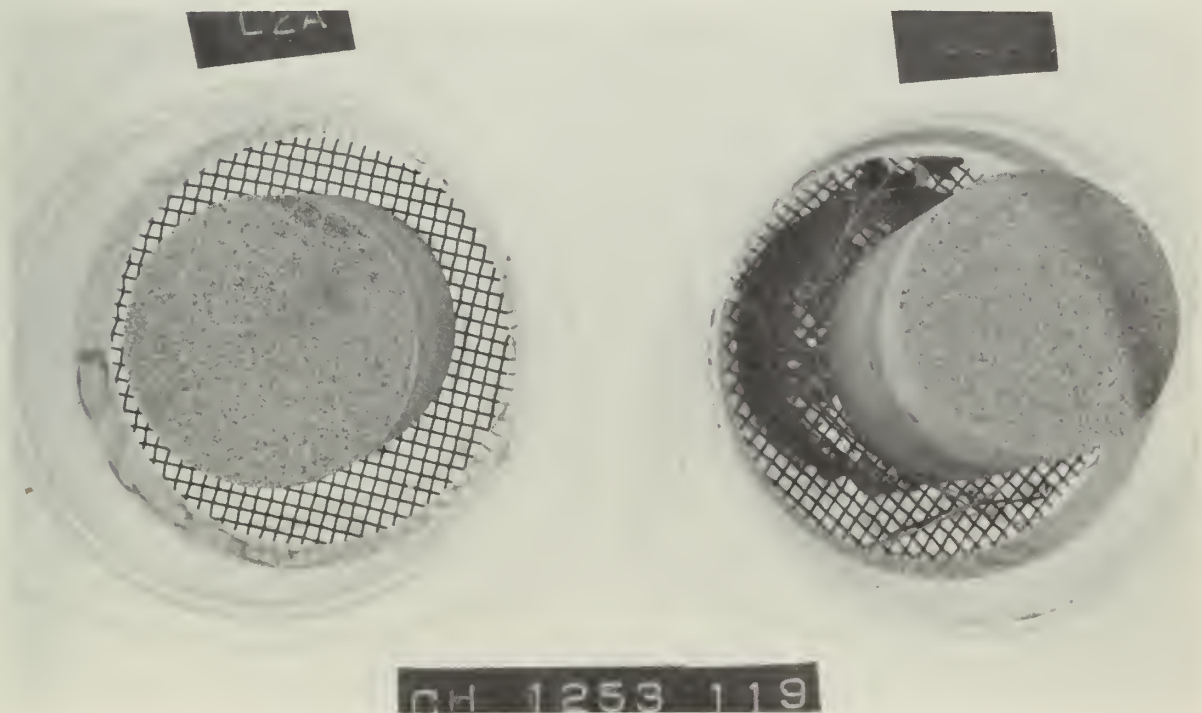
b. Condition of test specimens after weathering.

Figure L-2

Results of weathering tests for sandstone sample L-2. Specimen A subjected to 20 laboratory weathering cycles; specimen B subjected to 3 months of outdoor exposure.



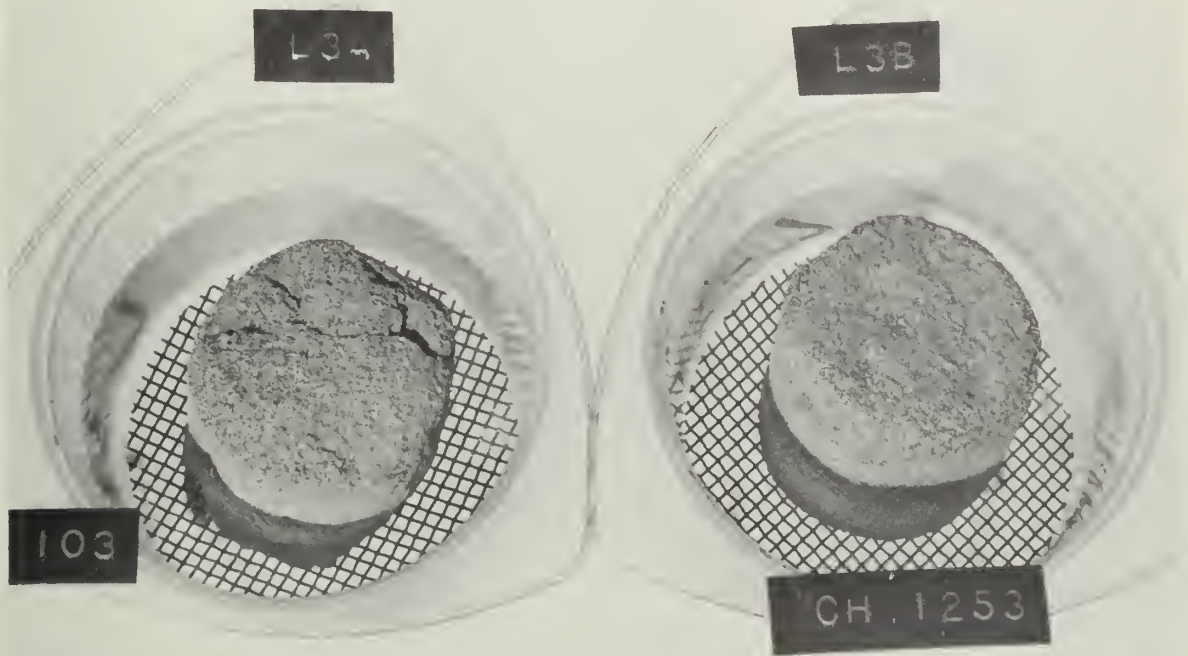
a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Figure L-3

Results of weathering tests for sandstone sample L-3. Specimen A subjected to 20 laboratory weathering cycles; specimen B subjected to 3 months of outdoor exposure.



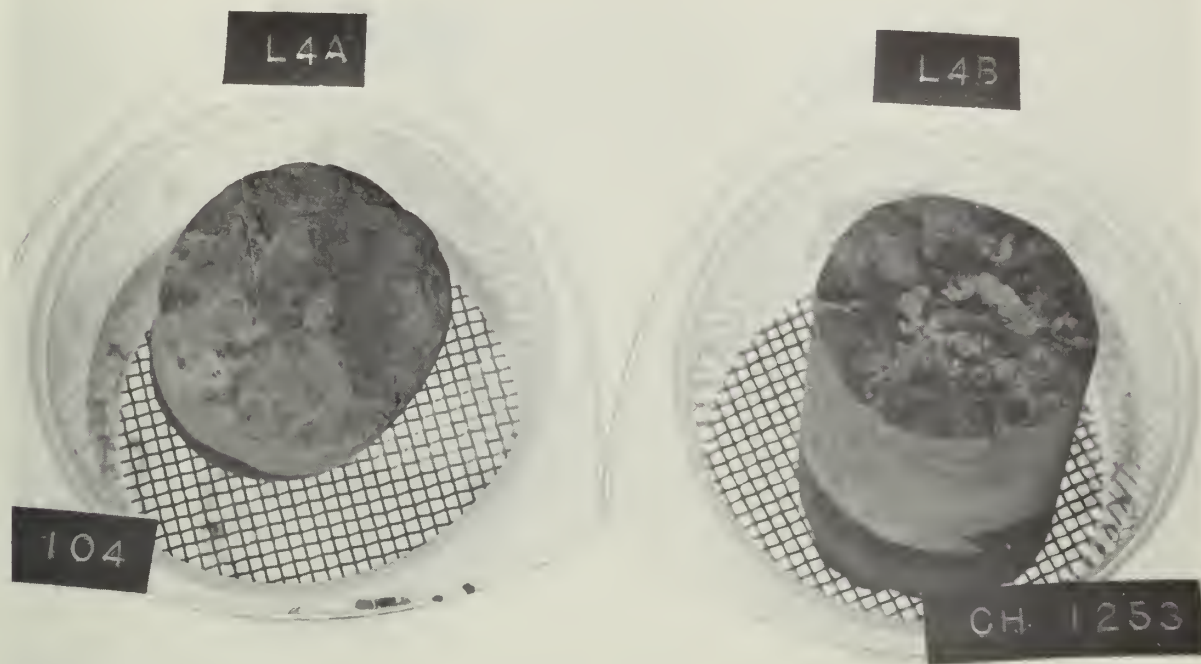
a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Figure L-4

Results of weathering tests for shale sample L-4. Specimen A subjected to 20 laboratory weathering cycles; specimen B subjected to 3 months of outdoor exposure.



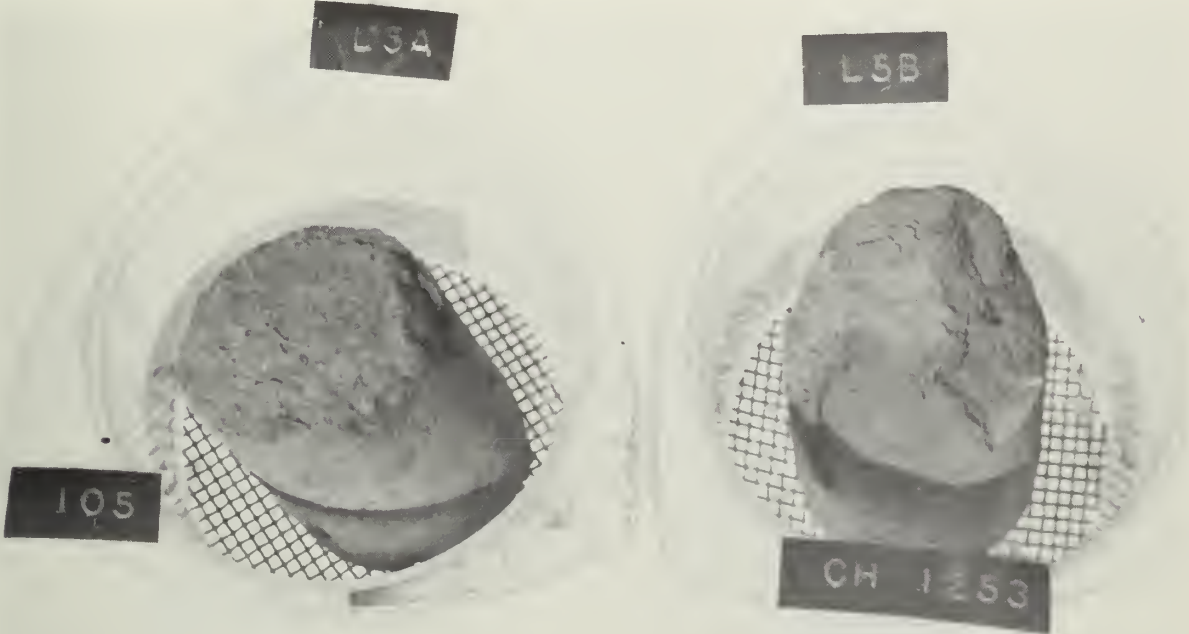
a. Original condition of test specimens.



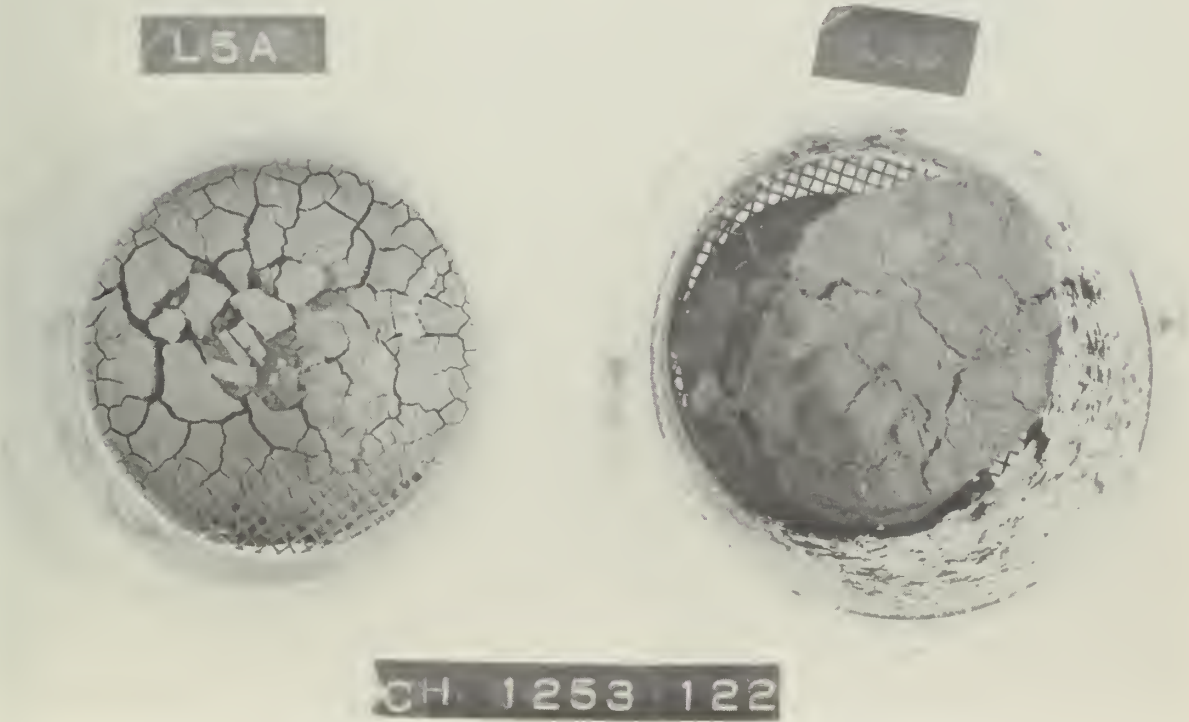
b. Condition of test specimens after weathering.

Figure L-5

Results of weathering tests for sandstone sample L-5. Specimen A subjected to 20 laboratory weathering cycles; specimen B subjected to 3 months of outdoor exposure.



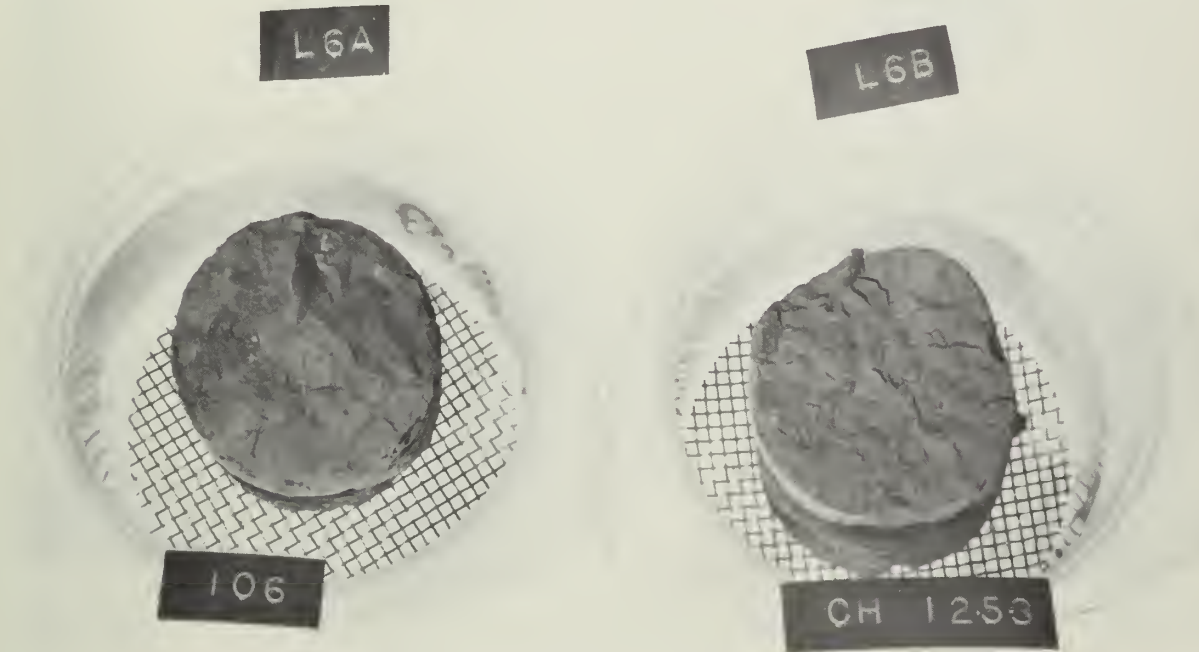
a. Original condition of test specimens.



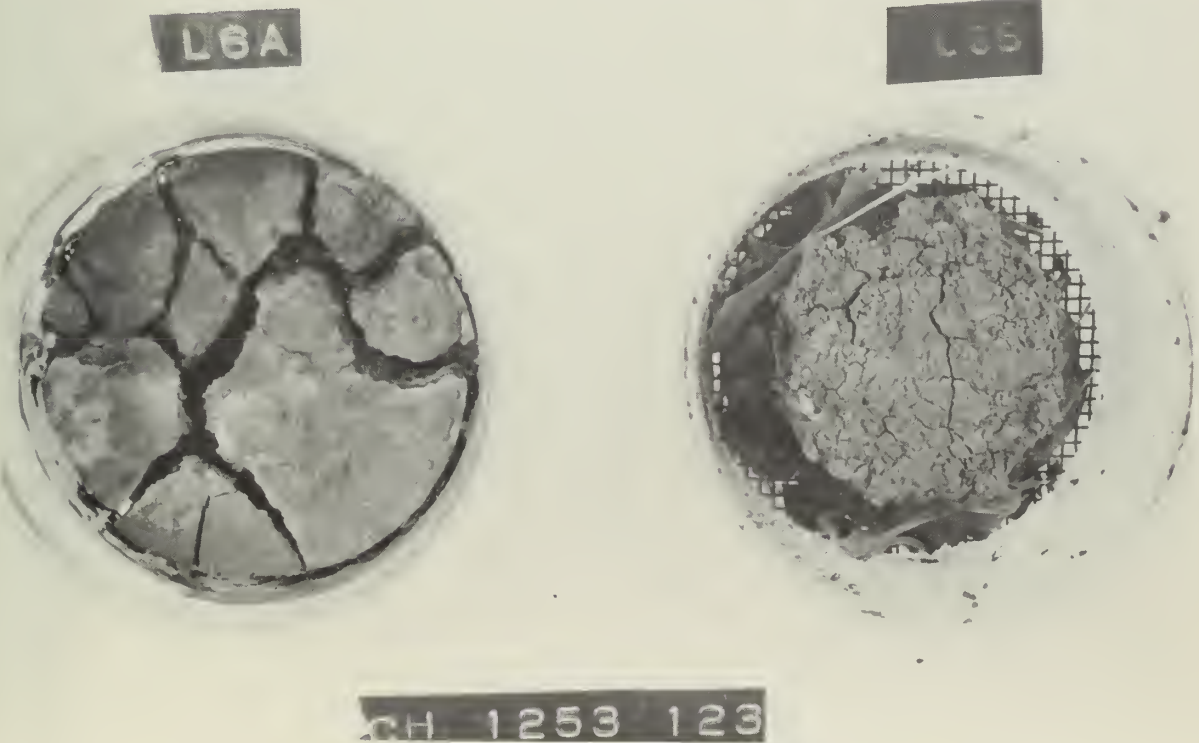
b. Condition of test specimens after weathering.

Figure L-6

Results of weathering tests for shale sample L-6. Specimen A subjected to 20 laboratory weathering cycles; specimen B subjected to 3 months of outdoor exposure.



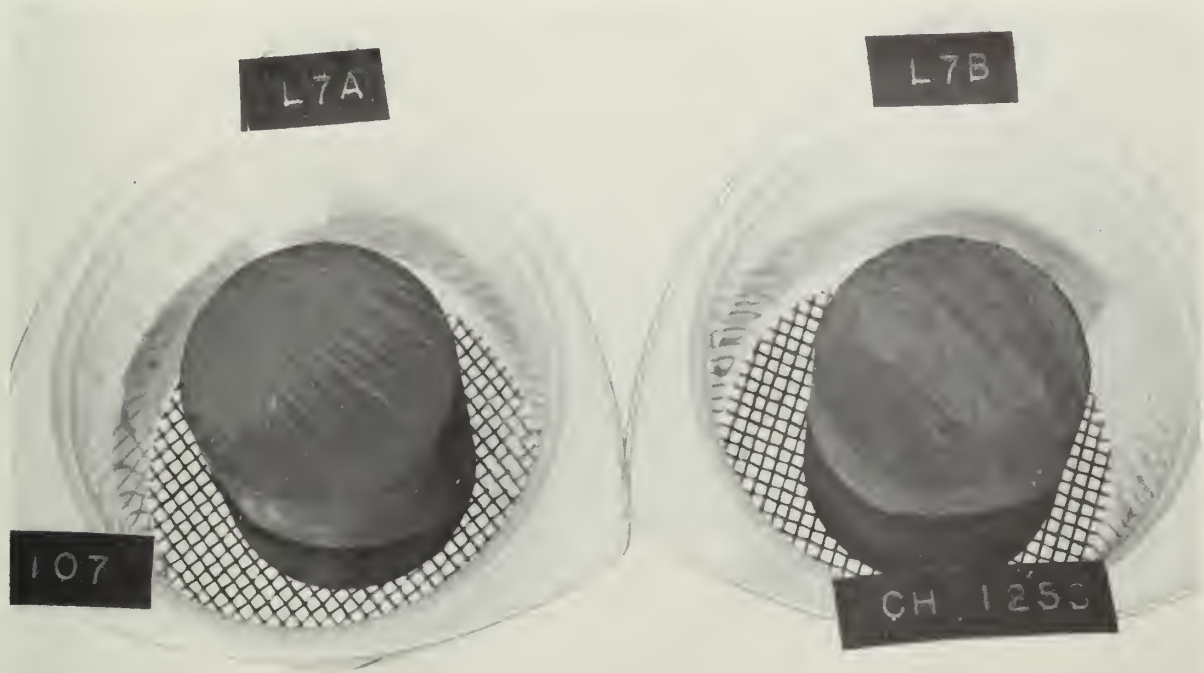
a. Original condition of test specimens.



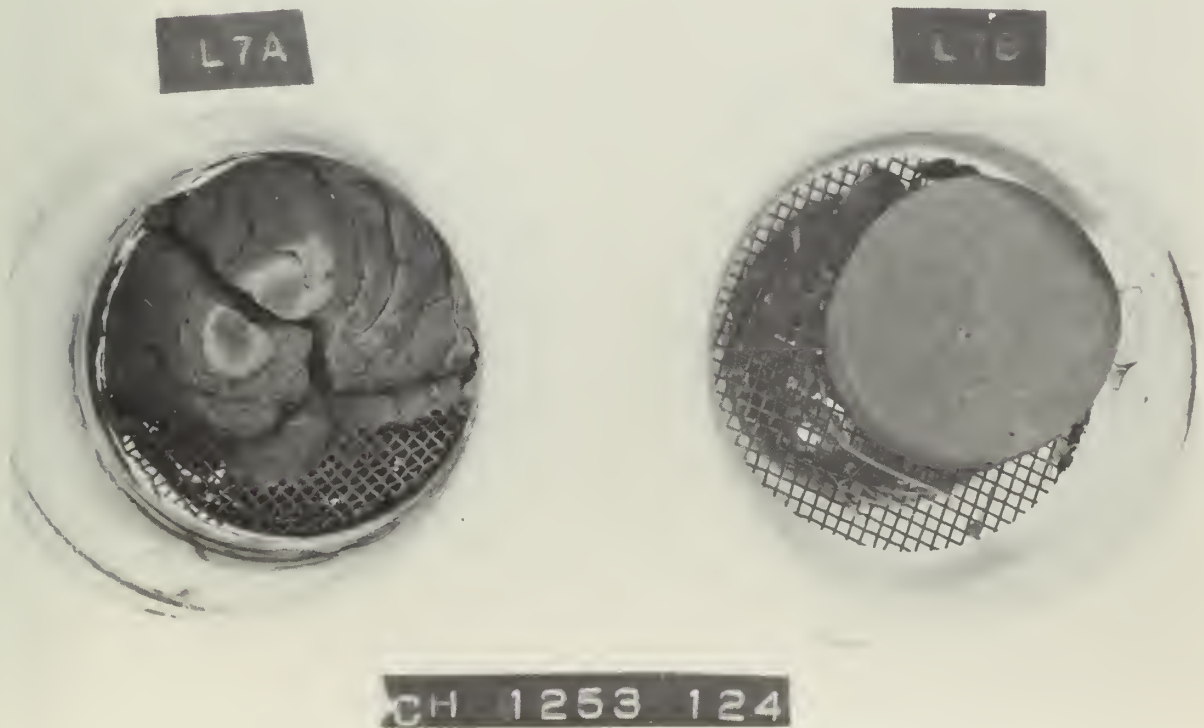
b. Condition of test specimens after weathering.

Figure L-7

Results of weathering tests for siltstone sample L-7. Specimen A subjected to 20 laboratory weathering cycles; specimen B subjected to 3 months of outdoor exposure.



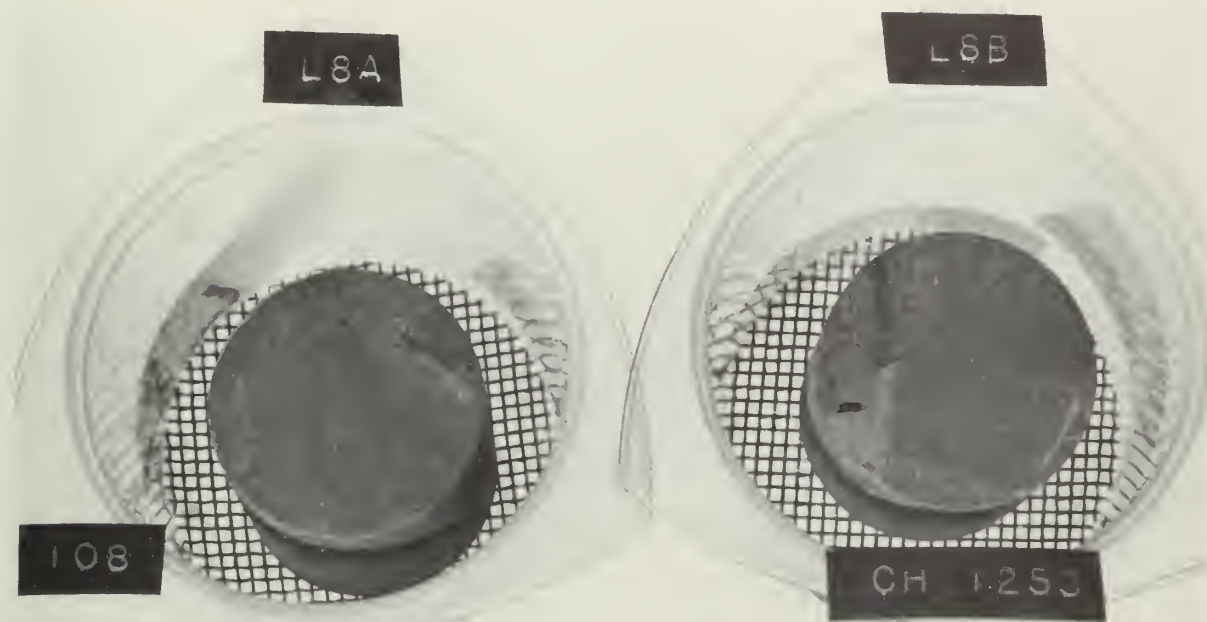
a. Original condition of test specimens.



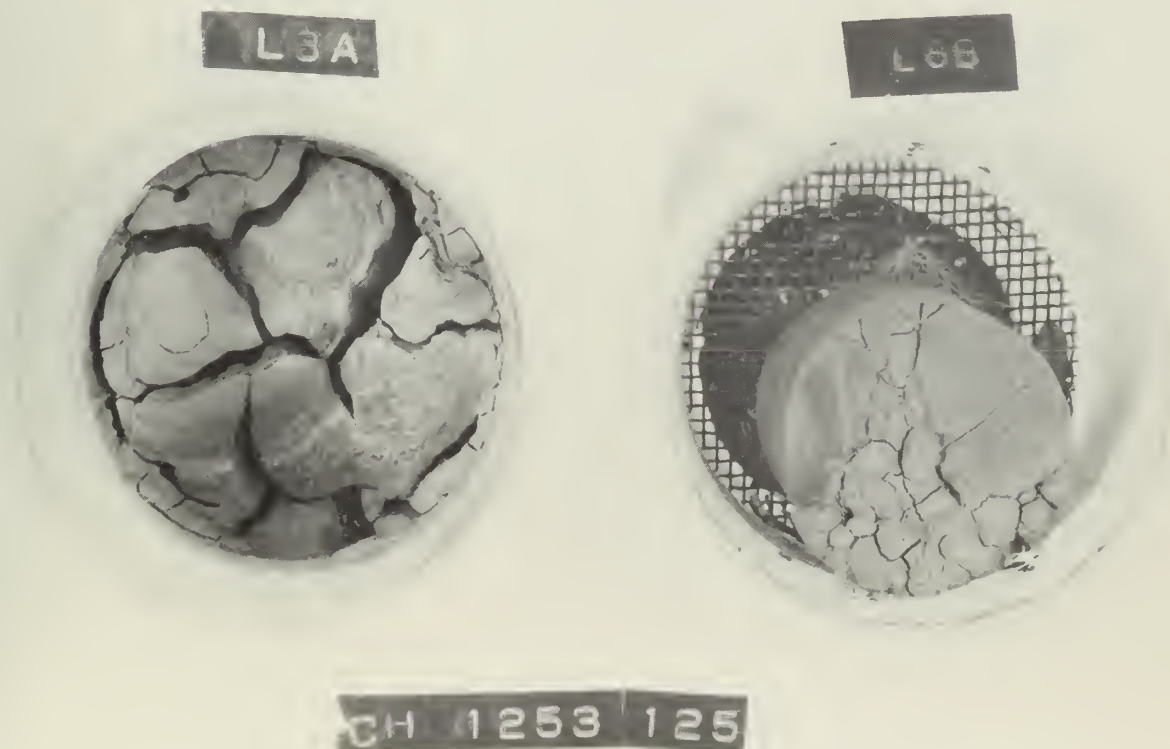
b. Condition of test specimens after weathering.

Figure L-8

Results of weathering tests for siltstone sample L-8. Specimen A subjected to 20 laboratory weathering cycles; specimen B subjected to 3 months of outdoor exposure.



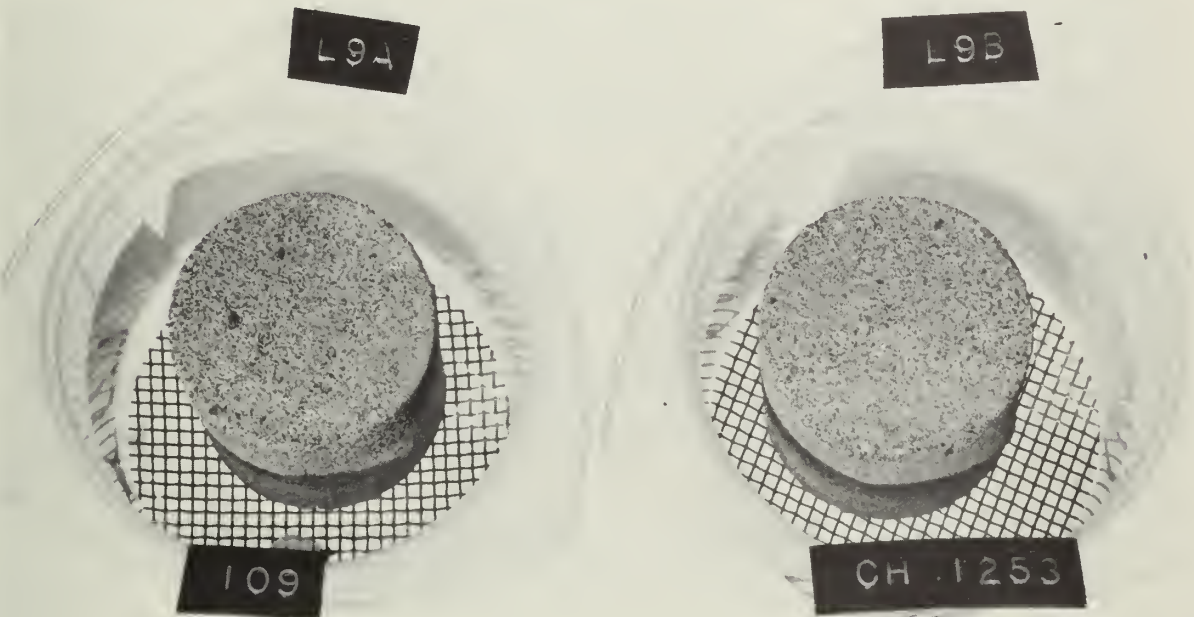
a. Original condition of test specimens.



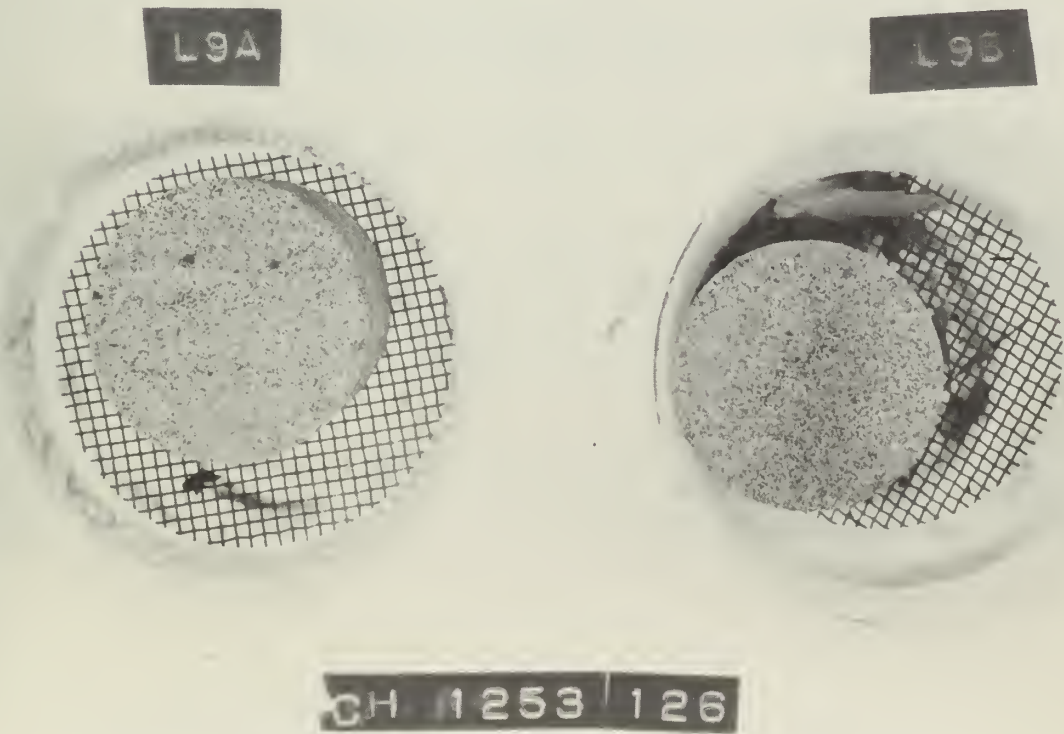
b. Condition of test specimens after weathering.

Figure L-9

Results of weathering tests for sandstone sample L-9. Specimen A subjected to 20 laboratory weathering cycles; specimen B subjected to 3 months of outdoor exposure.



a. Original condition of test specimens.



b. Condition of test specimens after weathering.

FINAL RESULTS OF WEATHERING TESTS CONDUCTED^{1/2/}
ON CORE SAMPLES FROM LAY CREEK, COLORADO

One-year outdoor exposure tests were completed on overburden core samples from the Lay Creek, Colorado, study area. The testing period was from June 8, 1979 through June 8, 1980. During this period of time the specimens were subjected to about 356 mm (14 inches) of precipitation. Results after 3 months of weathering were furnished in Applied Sciences Referral Memorandum Report No. 79-1-21, dated December 7, 1979.

The purpose of including outdoor exposure tests was to determine if any correlation could be drawn between this type of weathering and accelerated laboratory weathering previously reported in memorandum No. 79-1-21.

Test Results

Test results are summarized in table 1 and shown visually in figures 1 through 3.

At the completion of the outdoor exposure tests, a percent breakdown value (%BD) was determined for the specimens. This value listed under the remarks column in the table was derived as follows.

$$\%BD = \frac{(TW - IW)}{TW} (100)$$

where TW = total specimen weight
IW = weight of original specimen remaining intact after testing

In addition, the percent by weight passing a No. 10 mesh screen was determined for the specimens.

Of the 9 specimens tested, 2 sandstone materials, L-2 and L-9, exhibited little or no breakdown at all. The other 7 specimens exhibited various degrees of weathering, but only 3 attained the soil texture necessary as a planting medium (minimum of 30 percent by weight passing a No. 10 screen). The 3 specimens included shale sample L-1, sandstone sample L-3, and shale sample L-4.

With regard to the correlation between laboratory and outdoor weathering, the same type of breakdown of the specimens was observed in both cases. However, based upon the percent breakdown value (%BD), the outdoor weathering was slightly more severe.

^{1/} Progress Report FY-80.

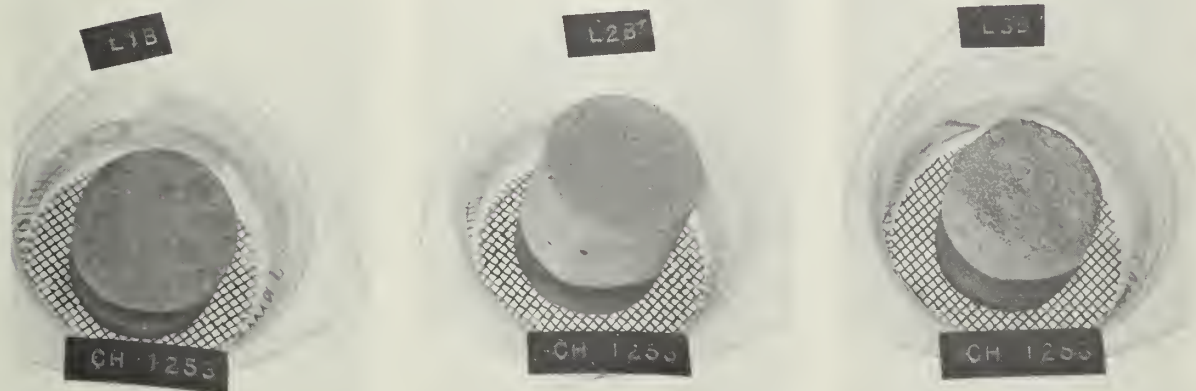
^{2/} Applied Sciences Referral Memorandum No. 80-1-18.

Table 1
Results of 1-year outdoor weathering for core samples
from Lay Creek, Colo.

Laboratory Sample Number	Sample I.D.			Remarks			
				Outdoor weathering	%BD	Passing No. 10 screen (percent)	Reference
	Sample	Depth (feet)					
L-1	Shale	DH-1	42.0- 50.6	Considerable slaking at 1 year.	100	79	See Figure 1
L-2	Sandstone	DH-1	84.5-110.8	No change at 1 year.	0	0	See Figure 1
L-3	Sandstone	DH-2	129.5-146.9	Specimen very friable at 1 year.	100	94	See Figure 1
L-4	Shale	DH-2	177.3-204.9	Considerable slaking at 1 year.	100	90	See Figure 2
L-5	Sandstone	DH-3	71.7- 86.9	Considerable slaking at 1 year.	100	5	See Figure 2
L-6	Shale	DH-3	102.6-123.9	Considerable slaking at 1 year.	77	2	See Figure 2
L-7	Siltstone	DH-3	225.4-254.1	Considerable slaking and delamination at 1 year.	60	9	See Figure 3
L-8	Siltstone	DH-4	95.5-111.3	Considerable slaking and delamination at 1 year.	74	3	See Figure 3
L-9	Sandstone	DH-4	120.4-192.0	No change at 1 year.	0	0	See Figure 3

Figure 1

Results of weathering tests for shale sample L-1, and sandstone samples L-2 and L-3 subjected to 12 months of outdoor exposure.



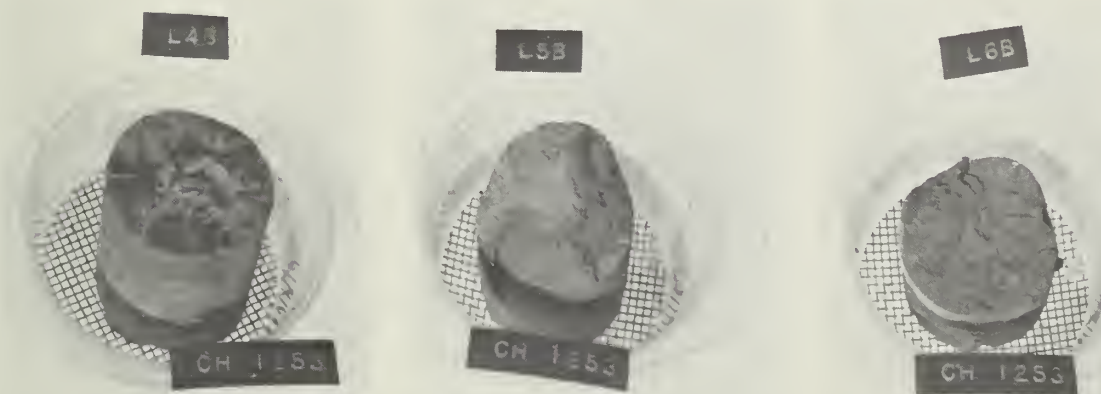
a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Figure 2

Results of weathering tests for shale samples L-4 and L-6, and sandstone sample L-5 subjected to 12 months of outdoor exposure.



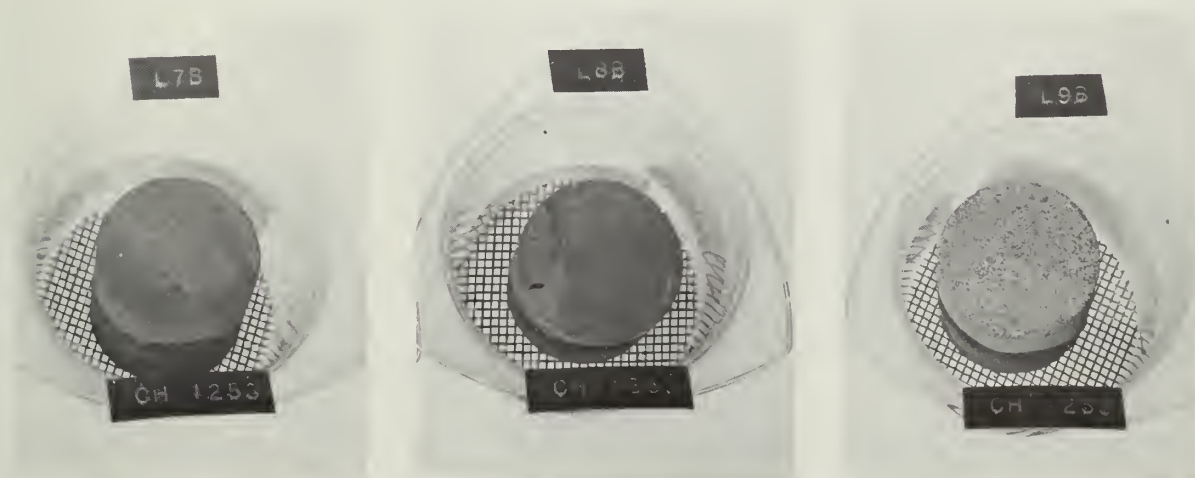
a. Original condition of test specimens.



b. Condition of test specimens after weathering.

Figure 3

Results of weathering tests for siltstone samples L-7 and L-8, and sandstone sample L-9 subjected to 12 months of outdoor exposure.



a. Original condition of test specimens.



b. Condition of test specimens after weathering.

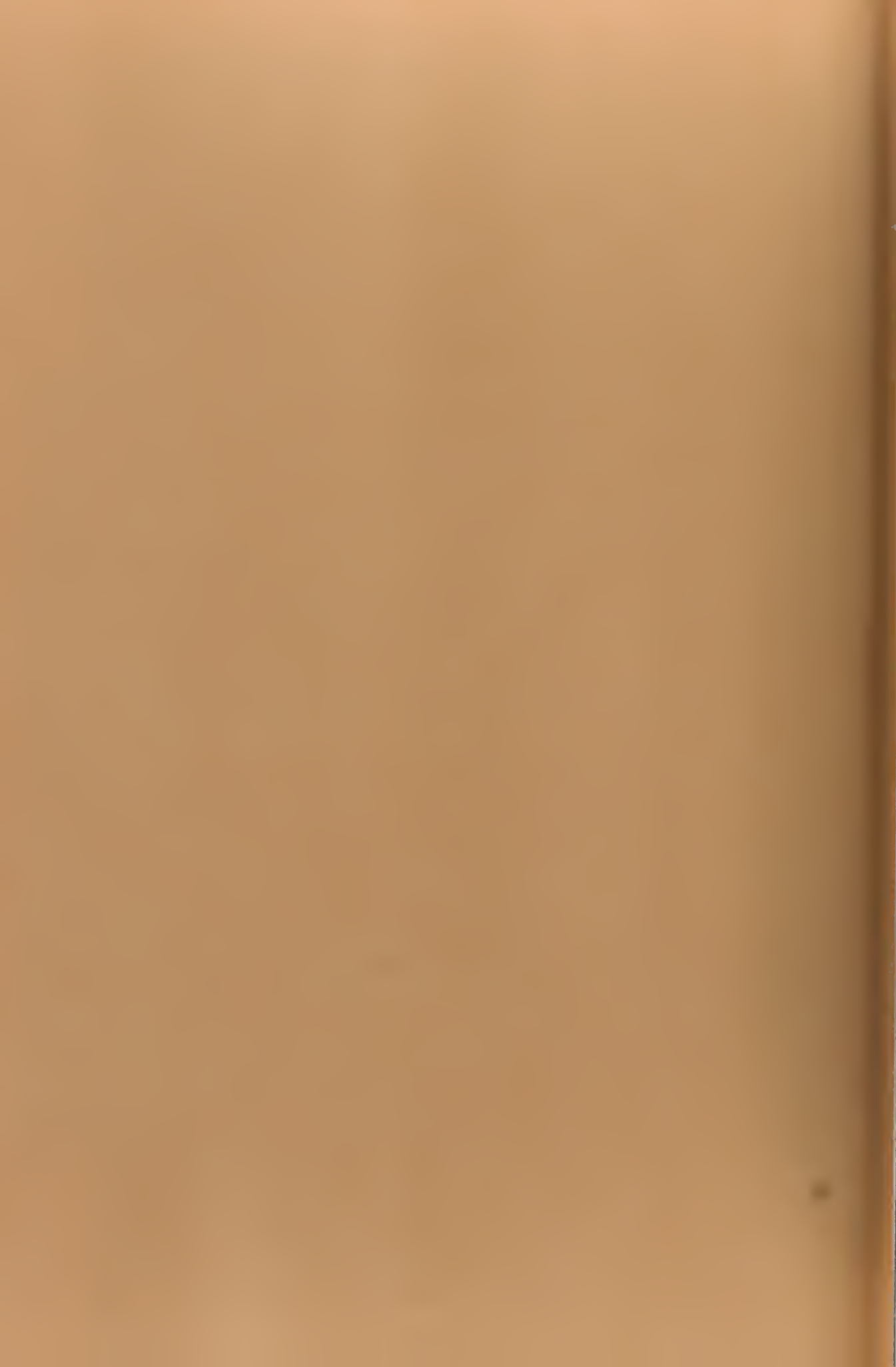
APPENDIX G

VEGETATION

Vegetation Found Within The
Lay Creek Study Area

This appendix includes the symbols, scientific names, and common names of plant species occurring within the Lay Creek Study Area.

United States Department of the Interior
Bureau of Land Management
District Office
Craig, Colorado



Appendix G
Vegetation

Symbol	Scientific names	Common names
Grasses		
Agcamz	<i>Agropyron caminum majus latiglume</i>	Slender wheatgrass
Agri	<i>Agropyron riparium</i>	Streambank wheatgrass
Agsm	<i>Agropyron smithii</i>	Western wheatgrass
Agsp	<i>Agropyron spicatum</i>	Bluebunch wheatgrass
Agrop	<i>Agropyron</i> spp.	Wheatgrasses
Brte	<i>Bromus tectorum</i>	Cheatgrass
Carex spp.	<i>Carex</i> spp.	Sedges
Elci2	<i>Elymus cinereus</i>	Basin wild rye
Feov	<i>Festuca ovina</i>	Sheep fescue
Juncus spp.	<i>Juncus</i> spp.	Rush species
Kocr	<i>Koeleria cristata</i>	Prairie junegrass
Orhy	<i>Oryzopsis hymenoides</i>	Indian ricegrass
Posa3	<i>Poa sandbergii</i>	Sandberg bluegrass
Poa spp.	<i>Poa</i> spp.	Native bluegrass
Sihy	<i>Sitanion hystrix</i>	Squirrel tail
Stco4	<i>Stipa comata</i>	Needle and thread grass
Stle4	<i>Stipa lettermanii</i>	Letterman needlegrass
Stipa spp.	<i>Stipa</i> spp.	Needlegrasses
Forbs		
Allium spp.	<i>Allium</i> spp.	Wild onion
Arfe	<i>Arenaria fendleri</i>	Fendler sandwart
Aster spp.	<i>Aster</i> spp.	Aster
Astra	<i>Astragalus</i> spp.	Milkvetch
Cheno	<i>Chenopodium</i> spp.	Goosefoot
Ciar4	<i>Cirsium arvense</i>	Canada thistle
Colli	<i>Collinsia</i> spp.	Collinsia
Colu	<i>Cordylanthus lutens</i>	Birdbeack
Crypt	<i>Cryptantha</i> spp.	Cryptantha
Descu	<i>Descurainia</i> spp.	Annual mustard
Erige	<i>Erigeron</i> spp.	Prairie fleabane
Eriog	<i>Eriogonum</i> spp.	Wild buckwheat
Grsq	<i>Grindelia squarrosa</i>	Curlycup gumweed
Haplo	<i>Haplopappus</i> spp.	Goldenweed
Hebo	<i>Hedysarum boreale</i>	Northern sweetvetch
Hirl	<i>Hieracium albiflorum</i>	White hawkweed
Lare	<i>Lappula redowskii</i>	Blue bur stickseed
Lomat	<i>Lomatium</i> spp.	Biscuit root
Luar3	<i>Lupinus argenteus</i>	Silvery lupine
Opuntia spp.	<i>Opuntia</i> spp.	Prickly pear cactus
Peca4	<i>Penstemon caepitosus</i>	Mat penstemon
Phho	<i>Phlox hoodii</i>	Hoods phlox
Phlo2	<i>Phlox longifolia</i>	Longleaf phlox
Phau5	<i>Physaria didymocarpa</i>	
	<i>didymocarpa</i>	Twinpod
Spco	<i>Sphaeralcea coccinea</i>	Globe mallow
Trdu	<i>Tragopogon dubius</i>	Yellow salsify
Shrubs		
Amal2	<i>Amelanchier alnifolia</i>	Serviceberry
Arlo	<i>Artemisia longiloba</i>	Alkali sagebrush
Ararn	<i>Artemisia arbuscula nova</i>	Black sagebrush

Vegetation (continued)		
Symbol	Scientific names	Common names
Shrubs (continued)		
Artem	<i>Artemisia</i> spp.	Sagebrush
Artr2	<i>Artemisia tridentata</i>	Big sagebrush
Atco	<i>Atriplex confertifolia</i>	Shadscale
Atrip	<i>Atriplex</i> spp.	Saltbush
Chna	<i>Chrysothamnus nauseosus</i>	Rubber rabbitbrush
Chvi	<i>Chrysothamnus viscidiflorus</i>	Douglas rabbitbrush
Ephed	<i>Ephedra</i> spp.	Mormon tea
Eula5	<i>Eurotia lanata</i>	Winterfat
Gusa2	<i>Gutierrezia sarothrae</i>	Broom snakeweed
Putr2	<i>Purshia tridentata</i>	Antelope bitterbrush
Save4	<i>Sarcobatus vermiculatus</i>	Black greasewood
Teca2	<i>Tetradymia canescens</i>	Gray horsebrush
Trees		
Juos	<i>Juniperus osteosperma</i>	Utah juniper
PPGG		Other perennial grasses
PPFF		Other perennial forbs
SSSS		Other shrubs
T		Trace

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